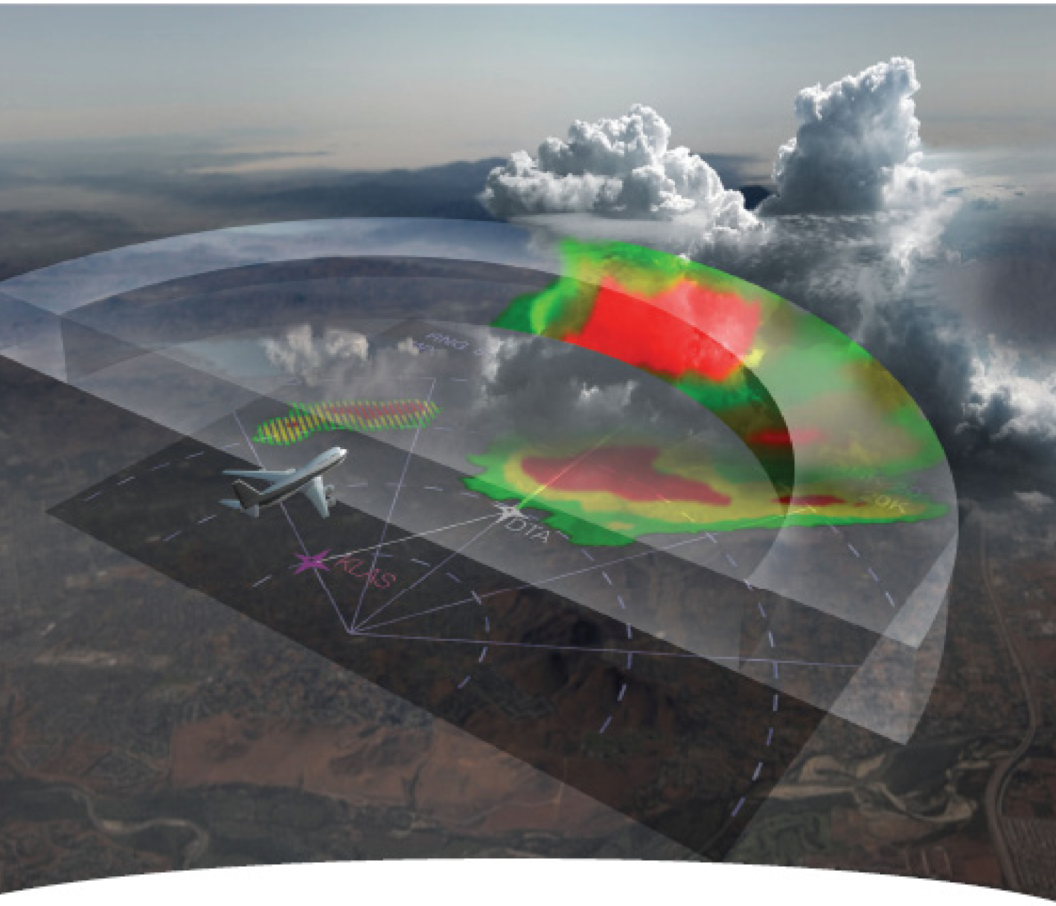
Honeywell

IntuVue™ RDR-4000



IntuVue 3-D Automatic Weather Radar System with Forward Looking Windshear Detection

For Boeing B737/B777 Aircraft

Pilot's Guide

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SECTION 1: INTRODUCTION

Welcome to Honeywell's IntuVue 3-D Automatic Weather Radar System, model RDR-4000. The RDR-4000 introduces several new technologies not found in current generation Radar Systems. Some of the major operational differences are highlighted here. Note that the availability of some features will depend on the installation configuration.

RDR-4000 OPERATIONAL ENHANCEMENTS

- Predictive Hail and Lightning Icons (if installed)
    - Areas ahead of the aircraft that have a high probability of producing hail or lightning are indicated by the display of appropriate icons.
- REACT (Rain Echo Attenuation Compensation Technique) (if installed)
    - Indicates areas where attenuation of the radar signal is severe enough to degrade the ability to display weather behind significant intervening weather.
- Automatic control of antenna tilt for reduced pilot workload
    - No traditional tilt control
- 3D Volumetric Memory
    - Entire sky in front of aircraft is automatically scanned (out to 320 nm and from ground to 60,000 feet)

  - All weather information is stored and continuously updated
  - Automatically corrects for curvature of the earth
  - Pilots can choose among display options as desired
- Internal Topography Database
  - Used to reduce ground clutter in weather displays and to reduce weather returns in the MAP display
- More sensitive weather detection for more accurate weather depiction
  - Improved long-range performance
  - 3D scanning detects more weather close to the aircraft as compared to conventional weather radar systems
- Differentiation of weather in and out of path of the aircraft
  - In AUTO mode, weather that is far above or below the aircraft's flight path is displayed in a different pattern than "Flight Path Weather"
  - In MAN mode, view horizontal slices through the weather in 1000-foot increments, from ground level to 60,000 feet
- Map mode for identification of terrain features
  - Use MAP mode for identifying prominent terrain features, such as coastlines, lakes, and large built-up urban areas.

The RDR-4000 is a technically advanced system, but as always, there are physical limitations to consider.

- The use of a topography database results in a significant reduction in ground returns. However, the database is not aware of man-made reflectors such as buildings at airports and cities. Therefore, it is possible that not all ground clutter will be eliminated.
- The antenna beam is very narrow at close ranges and widens significantly with range. Therefore, the resolution and accuracy of weather reflectivity is better at ranges closer to the aircraft.

OPERATIONAL LIMITATIONS AND CONSIDERATIONS

All of the limitations of the radar system have been consolidated here because of their importance. This section should be read thoroughly and frequently as a reminder of weather radar limitations.

- Airborne weather systems are not intended as a terrain or traffic collision avoidance system. Weather detection, analysis, and avoidance are the primary functions of the radar system.
- Your radar is a weather avoidance tool. It should never be used for weather penetration. It will help you see and plan avoidance maneuvers around significant weather encountered during flight.
- Radar detects rain drops and wet hail; not clouds, fog, dry hail, ice crystals, or snow.
- Hail and lightning icons are based on the detection of conditions that may lead to the development of hail or lightning in that general area – they do not indicate a direct detection of hail or lightning.
- It is important to remember that radars detect the presence of precipitation. Storm-associated turbulence without precipitation can extend several thousand feet above a storm and outward more than twenty nautical miles.
- Turbulence detection requires the presence of precipitation. Clear-air turbulence is not detected or displayed.
- The weather display corresponds to the selected range while the turbulence display is overlaid for the first 40 nm in AUTO mode (regardless of range selected). If the Hazard Display features are installed, turbulence will be displayed for the first 60 nm, and will be available in both AUTO and MAN modes.
- Hail and lightning icons indicate that conditions are conducive to the development of hail or lightning. Since this technology is predictive, icons often appear prior to the actual formation of the hail or lightning. Hence, the presence of icons does not guarantee that hail or lightning will be present. Similarly, the absence of an icon does not guarantee that the condition will not be present.
- Below 1800 feet windshear and weather antenna scans are interleaved. The windshear detection operation is transparent to the crew unless an alert is issued.
- Leave the system in TEST mode until it is safe to operate the radar. While in TEST mode there is no radiation hazard to nearby personnel.

- Reference the following Federal Aviation Administration (FAA) Advisory Circulars:
  AC 00-24B Thunderstorms
  AC 00-6A Aviation Weather
  AC 00-50A Low Level Wind Shear
  AC 20-68B Recommended Radiation Safety Precautions

SECTION 2: SIMPLIFIED OPERATING PROCEDURES

ON/OFF

There is no traditional OFF switch on the RDR-4000 control panel. The radar is always scanning while in flight so that the most current weather information is instantly available in the 3D memory.

The Radar is **OFF** (**Not Transmitting)** when:

- The System Control knob on the Radar control panel is set to TEST while the aircraft is on the ground and the PWS Qualifiers are not satisfied. (See AUTOMATIC WINDSHEAR ACTIVATION on page 18.)
- **Or** WXR is deselected on both Electronic Flight Display control panels while the aircraft is on the ground and the PWS Qualifiers are not satisfied. (See AUTOMATIC WINDSHEAR ACTIVATION on page 18.)

The Radar is **ON (Transmitting)** when:

- The System Control knob on the Radar control panel is set to L or R (dual system) or NORM (single system) and WXR is selected on at least one Electronic Flight Display control panel while the aircraft is on the ground.
- **Or** the PWS Qualifiers are satisfied while the aircraft is on the ground. (See AUTOMATIC WINDSHEAR ACTIVATION on page 18.)
- **Or** the aircraft is in the air, regardless of any other settings.

Radar data is shown on the display when:

- WXR is selected on the Electronic Flight Display control panel and TEST is NOT selected on the Radar control panel.
- **Or** there is a PWS Alert. (See WINDSHEAR ALERT REGIONS on page 18.)

TEST

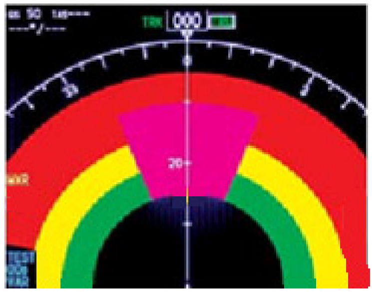
- System Control: TEST
- Mode: ANY
- Gain: CAL
- Range: 10 to 320 nm
- Select WXR on the Electronic Flight Display control panel.
- Note the test pattern on the display (various test patterns are available – see examples on page 7).
- Observe the Test Sequence shown below.
- Check for weather related fault messages on the display. (Fault messages are installation dependent. See FAULT ANNUNCIATIONS on page 36 for examples.)
- Some configurations will show a TEST COMPLETE indication on the test pattern once the test has finished. See test pattern examples on page 7.
- For systems without the TEST COMPLETE indication, leave the system in TEST for at least 50 seconds to ensure test completion.
- For a dual system select TEST on the other system and repeat.
- During test mode there is no radiation hazard to personnel in the vicinity of the aircraft.
- The configuration of the RDR-4000 installed in your aircraft can be determined by examining the test pattern and referring to the images on page 7.
- Leave the system in TEST mode until it is safe to operate the radar. When safe to do so select NORM or L/R.

Test Sequence

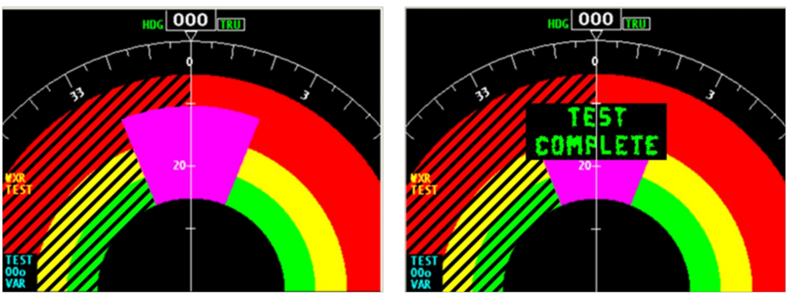
Time TEST Selected	Approx. 2 Sec.	Approx. 4 Sec.	Approx. 6 Sec.
PWS FAIL/INOP	On	OFF ("ON" if failure is detected)	
PWS VISUAL ALERTS	Off	Amber (WINDSHEAR)	Red (WINDSHEAR)
PWS AURAL ALERTS	None	Tone "Whoop, Whoop" or "Monitor Radar Display"	"Go Around, Windshear Ahead, … Windshear Ahead, Windshear Ahead"
DISPLAY	Normal Test Pattern (No PWS Icon)		

"Whoop, Whoop" or "Monitor Radar Display" is selected at installation.

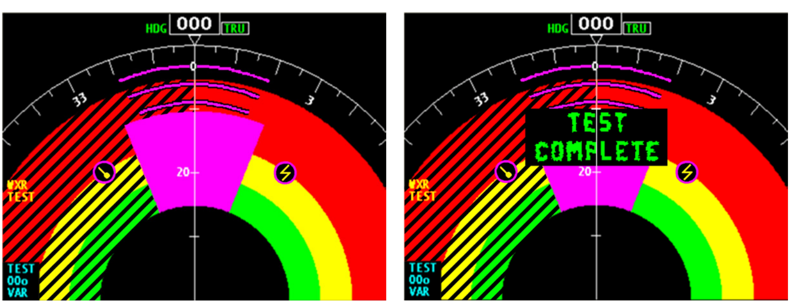
TEST PATTERNS



Configurations without Hazard Display Features or Test Complete Indication.



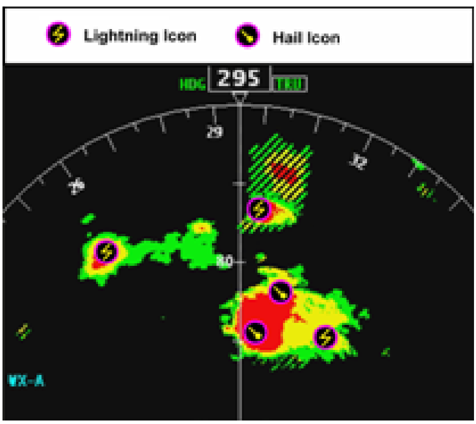
Configurations without Hazard Display Features, but with Test Complete Indication.



Configurations with Hazard Display Features (includes Test Complete Indication).

TAKEOFF AND DEPARTURE

- System Control: L or R (dual system) or NORM (single system)
- Mode: AUTO
- Gain: CAL or as required to assess threats. (Refer to GAIN CONTROL on page 27 for more details.)
- Range: Pilot Flying – 10 to 40 nm, other side at least one range higher.
- Avoid any magenta turbulence cells and monitor the display for weather intensity to avoid any weather threats.
- Avoid any cells associated with Hail or Lightning Icons.
- Avoid areas where the REACT field is shown (see page 17).
- If there is weather in the area, ensure that the radar has been turned on in time to allow pilot(s) to evaluate any threats prior to takeoff.
- See *PLANNING A PATH* on page 42 for more information.

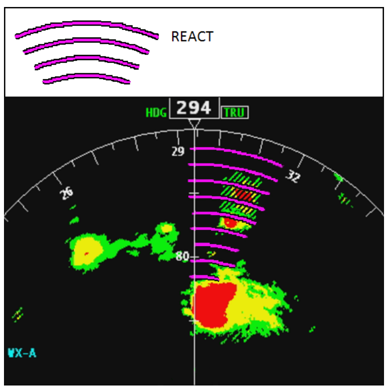


CLIMB UP TO FL200

- System Control: L or R (dual system) or NORM (single system)
- Mode: AUTO
- Gain: CAL or as required to assess threats. (Refer to GAIN CONTROL on page 27 for more details.)
- Range: Pilot Flying – 10 to 40 nm, other side at least one range higher
- Avoid any magenta turbulence cells and monitor the display for weather intensity to avoid any weather threats.
- Avoid any cells associated with Hail or Lightning Icons.
- Avoid areas where the REACT field is shown (see page 17).
- See *PLANNING A PATH* on page 42 for more information.

CRUISE ABOVE FL200

- System Control: L or R (dual system) or NORM (single system)
- Mode: AUTO
- Gain: CAL or as required to assess threats. (Refer to GAIN CONTROL on page 27 for more details.)
- Range: Pilot Flying – 20 to 80 nm, other side at least one range higher.
- Within 60 nm sufficient resolution exists for evaluating cells. At this point Flight Path and Secondary weather will become more prominent and MAN mode can be used for vertical analysis.
- Avoid any magenta turbulence cells and monitor the display for weather intensity to avoid any weather threats.
- Avoid any cells associated with Hail or Lightning Icons.
- Avoid areas where the REACT field is shown (see page 17).
- See PLANNING A PATH *on page 42* for more information.



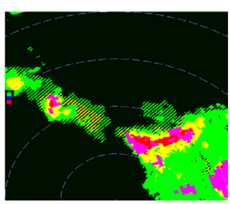
DESCENT AND APPROACH

- System Control: L or R (dual system) or NORM (single system)
- Mode: AUTO
- Gain: CAL or as required to assess threats. (Refer to GAIN CONTROL on page 27 for more details.)
- Range: Pilot Flying – 10 to 40 nm, other side at least one range higher.
- Avoid any magenta turbulence cells and monitor the display for weather intensity to avoid any weather threats.
- Avoid any cells associated with Hail or Lightning Icons.
- Avoid areas where the REACT field is shown (see page 17).
- Start evaluating cells by 40 nm and finish by 20 nm.
- Make your weather decision by the 20 nm point.
- See PLANNING A PATH *on page 42* for more information.

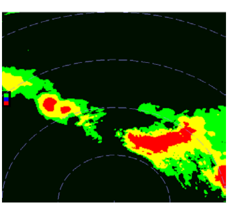
AVOIDANCE MANEUVERS

When considering avoidance maneuvers keep the following in mind:

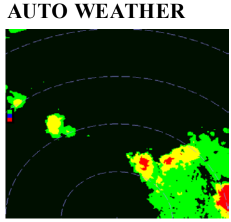
- Never deviate under a storm cell or the associated anvil.
- Plan deviations on the upwind side of storm cells to avoid turbulent downflow air.
- When flying between storm cells allow at least 40 nm separation.
- Damaging hail can be thrown at least 20 nm from the storm cell by upper level winds.
- Avoid all yellow, red, or magenta areas.
- Avoid any cells associated with Hail or Lightning Icons by at least 20 nm.
- Avoid areas where the REACT field is shown (see page 17).
- Establish an avoidance plan before getting within 40 nm of the cells to allow time to negotiate a deviation with ATC. (See PLANNING A PATH *on page 42* for more information).
- The height of a storm cell should also be considered when planning avoidance.
    - Avoid all green, yellow, red, and magenta areas of cells taller than 28,000 feet by at least 20 nm.
    - Cells exceeding 35,000 ft should be considered extremely hazardous and additional separation (in addition to the 20 nm) should be used.



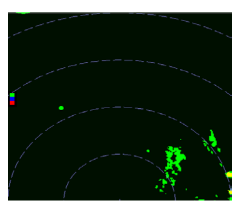
AUTO WEATHER



MAN MODE:
SLICE AT 10,000 FT
(10,000 FT BELOW A/C)



MAN MODE:
SLICE AT 20.000 FT
(AT A/C ALTITUDE)

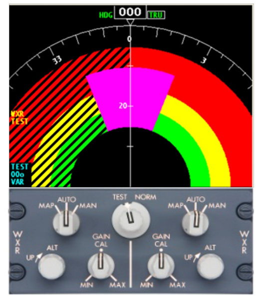


MAN MODE:
SLICE AT 30,000 FT
(10,000 FT ABOVE A/C)

SECTION 3: EXPANDED OPERATING INSTRUCTIONS

TURN ON AND TEST

Prior to leaving the gate, perform a system TEST. This will provide a comprehensive check of system performance. For turn on and test use the following procedure:



1. Turn the Radar on by selecting weather (WXR) on at least one display.
2. Set the radar system controls as follows:
   a. System Control: TEST.
   b. Gain: CAL.
   c. Range Selection: any range.

The system initiates Built-In Test (BIT) when TEST mode is selected for more than five seconds. While in TEST mode, a test pattern is transmitted to the active displays. The following table indicates the timing sequence of visual and aural alerts for normal operations.

Time TEST Selected	Approx. 2 Sec.	Approx. 4 Sec.	Approx. 6 Sec.
PWS FAIL/INOP	On	OFF ("ON" if failure is detected)	
PWS VISUAL ALERTS	Off	Amber (WINDSHEAR)	Red (WINDSHEAR)
PWS AURAL ALERTS	None	Tone "Whoop, Whoop" or "Monitor Radar Display"	"Go Around, Windshear Ahead, … Windshear Ahead, Windshear Ahead"
DISPLAY	Normal Test Pattern (No PWS Icon)		

"Whoop, Whoop" or "Monitor Radar Display" is selected at installation.

3. Check the display:
   a. Confirm the presence of test bands. The test pattern display is similar for all ranges. See test pattern examples on page 7.
   b. Confirm that the alphanumeric legends are displayed.
   c. If the test bands are missing and the name of a line replaceable unit (LRU) appears on the display, there is a fault in that unit. Refer to FAULT ANNUNCIATIONS on page 36.

The antenna will remain parked except for a momentary test where a box-shaped scan pattern is performed once. This test does not pose a hazard to personnel on the ground. Test mode will complete in approximately 50 seconds. Some electronic displays may display test information differently. Refer to the Airplane Flight Manual or Supplement for specific annunciations related to the weather radar.

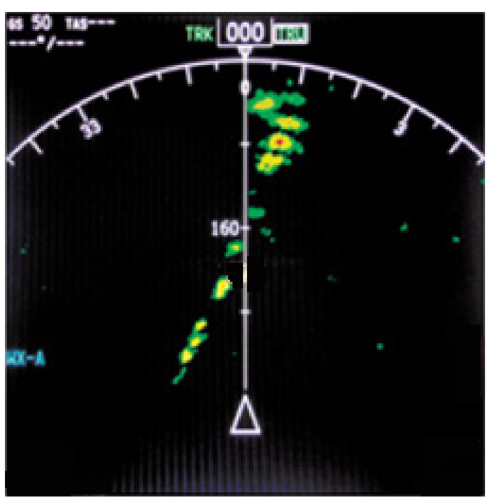
SYSTEM SELECTION

Radar data is displayed whenever WXR mode is selected on any electronic display or on a dedicated radar indicator. When on the ground, the radar will not transmit if WXR is deselected, or if the radar is in TEST mode. When in the air the radar scans continuously, always updating the memory so that current weather is immediately available. This is true even if TEST is selected, or if WXR is deselected on all displays. (See also ON/OFF on page 5.).

Dual radar systems (two independent radar processing systems) include the CP-1B control panel. In this case, place the System Control Knob in either the **L** or **R** position to select the left or right system for normal weather mode.

Single radar systems (only one radar processing system) utilize the CP-1A control panel. In this case, place the System Control Knob in the **NORM** position to select the normal weather mode.

Upon initial activation of the radar, or when switched from one system to the other (L or R), the radar first looks at the part of the sky that is near the aircraft's altitude. This data is displayed as soon as it is available. As data is gathered from the remainder of the sky in front of the aircraft, the display quickly fills in with any additional information. It takes no more than 30 seconds for the complete picture to become available. Note that when switching from one system to the other, the weather depicted may not exactly match what was previously displayed due to the loss of "historical" data from the other system. Therefore, there is no advantage in switching from one side of the radar to the other, except in the case of the failure of one side.

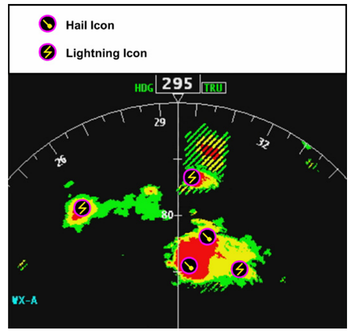


WEATHER DETECTION

AUTOMATIC WEATHER MODE (AUTO)

GENERAL DESCRIPTION

AUTO mode provides weather, turbulence, and predictive windshear detection. The system processes the data to fill the 3D memory and extracts the selected data for display. When a PWS event is detected, an icon is shown on the display. Returns determined to be ground clutter are not shown.



Weather targets are color-coded by the intensity of the return. The display correlation to approximate rainfall (with Gain set to CAL) is as follows:

Reflectivity Color Codes (Gain at CAL)

Color	Returns	Reflectivity	Rainfall Rate
Black	Very light or none	Less than 20 dBz	Less than 0.7 mm/hr (0.028 in/hr)
Green	Light	20 – 30 dBz	0.7 – 4 mm/hr (0.028 – 0.16 in/hr)
Yellow	Medium	30 – 40 dBz	4 – 12 mm/hr (0.16 – 0.47 in/hr)
Red	Strong	40 dBz or greater	Greater than 12 mm/hr (0.47 in/hr)
Magenta	Turbulence	N/A	N/A

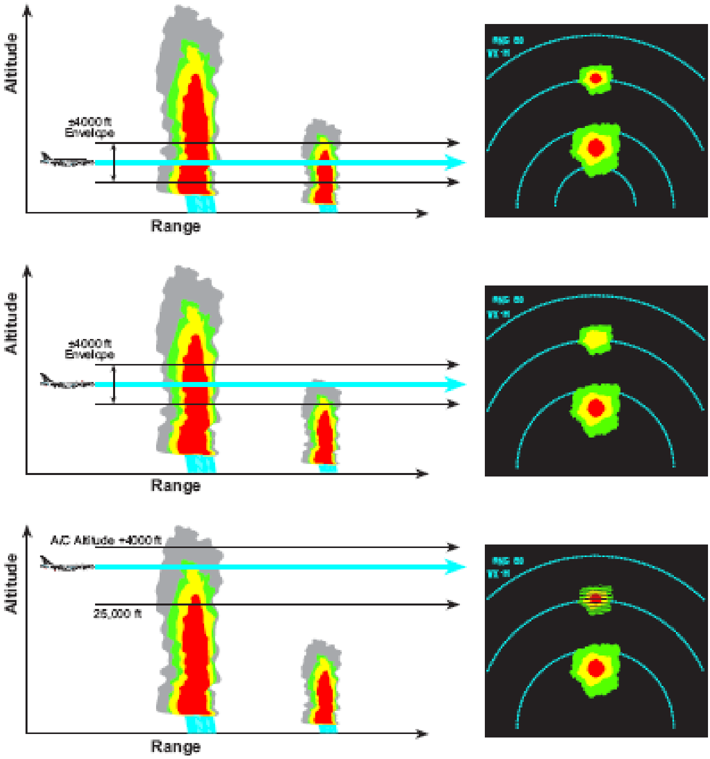
FLIGHT PATH WEATHER

The RDR-4000 fills the 3D memory with all the detected weather in front of the aircraft out to 320 nm, and from ground level up to 60,000 feet mean sea level (MSL). The RDR-4000 designates weather along the flight path as “flight path” weather. All other weather is designated as “secondary” weather, and is displayed with black stripes through it.

The nominal flight path weather envelope is ±4000 feet with respect to the expected flight path. To aid the pilot, at certain altitudes and flight path slopes this envelope is expanded. At cruise altitudes the floor of the envelope is fixed at 25,000 feet MSL. This ensures the display of convective activity associated with less reflective frozen storm tops. On the ground and during departure or approach the ceiling of the envelope is fixed at 10,000 feet MSL. This provides approximately ten minutes of look-ahead.

SECONDARY WEATHER

Secondary weather is displayed for situational awareness and to aid in making changes to your flight plan to avoid "flight path" weather. See the examples to visualize the displayed weather.



UNDERSTANDING THE DISPLAY IN AUTO MODE

In AUTO mode, the RDR-4000 projects a three dimensional memory space onto a two dimensional display. This means the weather displayed for any one memory cell is the color of the strongest return in that column of memory cells. Specifically, if there is any weather data in a given column that is inside the envelope for "flight path" weather; the color of the strongest of these returns is displayed. If there is no weather data inside the envelope, then the color of the strongest return from outside the envelope is displayed as “secondary” weather.

Stronger returns outside the envelope ("secondary" weather) never override the strongest returns displayed as "flight path" weather.

TURBULENCE DETECTION

Turbulence detection is an automatic function of this weather radar system.

For turbulence detection and evaluation use the following procedure:

1. System Control: L or R (or NORM for single system)
2. Mode: AUTO (also available in MAN mode if the Hazard Display Configuration is installed).
3. Range: As desired

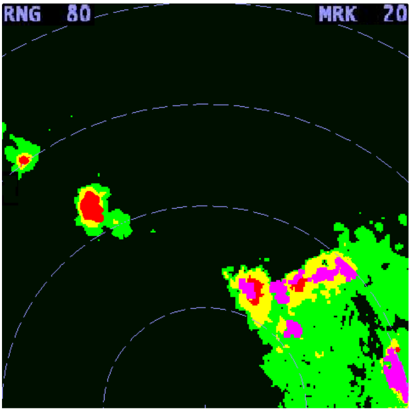
Turbulence information is limited to the first 40 nautical miles (60 nautical miles if the Hazard Display Configuration is installed). Turbulence within this range and inside the flight path weather envelope will be displayed in magenta.

The turbulence data is represented in a "blocky" shape, helping to visually differentiate it from reflectivity data.

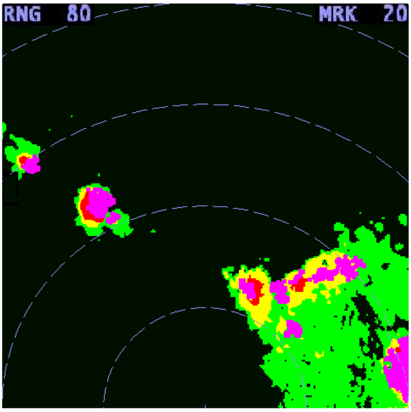
The turbulence detection feature of the RDR-4000 is quite sensitive as compared to previous radar functionality. The threshold for displaying indications of turbulence is based on the potential aircraft response to that turbulence. Therefore, magenta blocks may be displayed on top of any color, including black.

If the Hazard Display Configuration of the radar system is installed, the GAIN knob can be used to temporarily suppress the display of Hazard Icons and Turbulence Indication. See HAZARD DISPLAY SUPPRESSION on page 29 for details.

Typical Turbulence Display



Limited to 40 nm



Extended to 60 nm

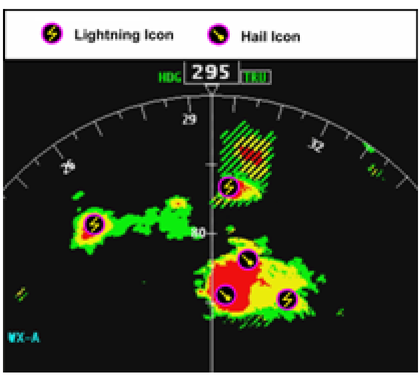
PREDICTIVE HAIL AND LIGHTNING (Hazard Display Feature)

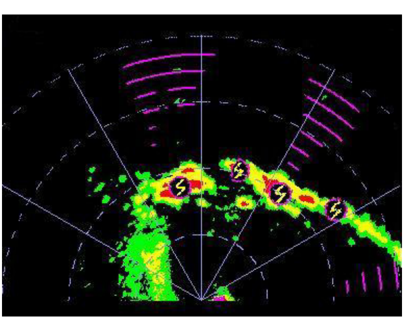
If the Hazard Display Configuration of the radar system is installed, icons will be displayed on top of the reflectivity to identify areas that have the signature characteristics of hail, lightning, or both. The radar does not directly detect hail or lightning; it analyzes the data in the 3D memory to identify areas that have a high probability of containing these hazards. While an experienced pilot can use techniques such as those mentioned in Storm Cell Characteristics on page 40 to determine this information, the display of hail or lightning icons simplifies this task.

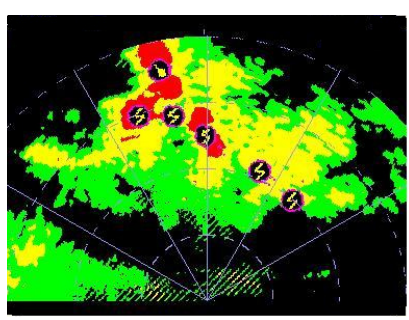
Hail and lightning icons indicate that conditions in the associated weather cell are conducive to the development of hail or lightning. They do not guarantee that hail or lightning will be present, nor does the absence of an icon guarantee that the condition will not be present. Note that an icon cannot indicate the exact location of any expected hail or lightning. Treat the entire weather cell or area as a threat.

See “*PATH PLANNING CONSIDERATIONS*” on page 43 for details on how to utilize the information provided by the Hail and Lightning Icons.

If the Hazard Display Configuration of the radar system is installed, the GAIN knob can be used to temporarily suppress the display of Hazard Icons and Turbulence Indication. See HAZARD DISPLAY SUPPRESSION on page 29 for details.

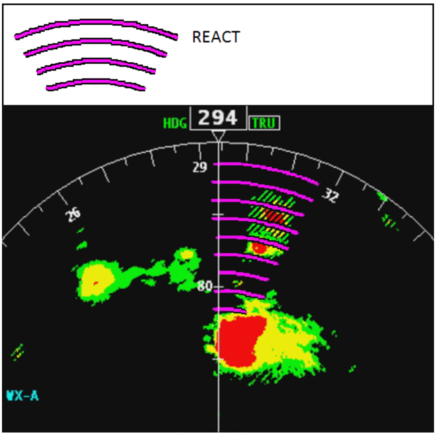


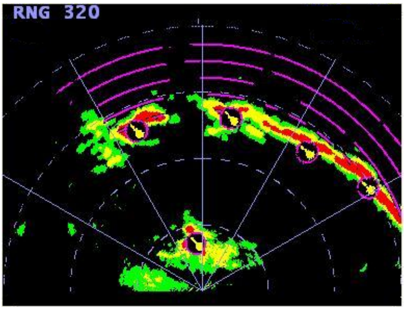


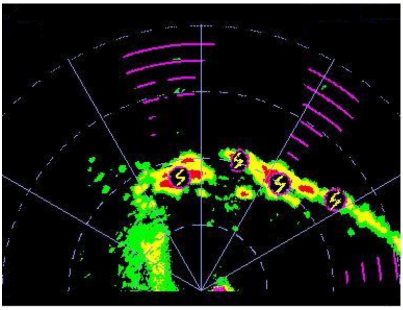


REACT (Hazard Display Feature)

REACT stands for *Rain Echo Attenuation Compensation Technique*. As the transmitted radar signal travels through heavy rain it loses power, or becomes attenuated. If this attenuation is severe enough, weather behind a storm cell may not be detectable, or it may be displayed as being less severe than it actually is (e.g. green instead of yellow). While the pilot can use techniques such as those described in *Shadowed Areas* on page 45 to identify this condition, the Hazard Display Configuration of the RDR-4000 automatically indicates areas where the radar signal has been attenuated. These areas are shown as magenta arcs superimposed over the reflectivity in the areas where the signal attenuation is significant. These arcs indicate that there could be severe weather in that area, even though only mild or no reflectivity is shown. Plan to avoid areas marked with magenta arcs.







PREDICTIVE WINDSHEAR (PWS) DETECTION

The Predictive Windshear feature detects the presence of windshear ahead of the aircraft, giving 10 to 60 seconds of warning before the encounter. Windshear detection mode operates automatically below 1800 ft Above Ground Level (AGL), with alerts available at 1500 ft AGL and below. If a Windshear event is detected, the system automatically provides the crew with Caution and/or Warning annunciations, and a Windshear icon appears on the weather display. This system is meant to supplement other means of detecting and avoiding hazardous Windshear conditions. It will not detect all possible hazardous Windshear conditions such as extremely dry events or events masked by unusual radar clutter.

AUTOMATIC WINDSHEAR ACTIVATION

The Windshear mode will automatically be turned on under the following specific aircraft conditions:

In Air: Below 1800 ft. AGL
On Ground: Typically Engine at Take-Off Thrust Setting
or both Oil Pressure Active **and** Transponder On
or the Runway Awareness Advisory System (RAAS) – if installed, indicates “On Runway”

WINDSHEAR ALERT REGIONS

The PWS mode can generate three types of alerts; **Advisory, Caution,** and **Warning**. These depend on the location of the Windshear event, not the strength. When a Windshear event is encountered below 1500 ft AGL, the appropriate alert is issued and the icon automatically appears on the display.

If the display is showing data other than weather (such as ground proximity terrain data) when a Windshear event takes place, the display automatically switches into weather mode for presentation of the Windshear icon. The Windshear Icon will be overlaid on the radar display indicated by the mode selection knob on the control panel.

If a Windshear event is encountered while the system is in TEST, the test pattern will be replaced, and the Windshear icon will be overlaid on an AUTO weather display.

Two different configurations are available for windshear alert regions and windshear alert inhibit regions. The following pages describe what alerts are shown for each, and how the inhibit regions differ between the two configurations. The configuration is selected during installation.

ADVISORY ALERTS

The Advisory Alert region is ±40° from the aircraft track and from 0.5 nm to 5.0 nm in front of the aircraft.

- Configuration A:
  Between 50 ft and 1,500 ft AGL the system indicates ADVISORY Alerts by overlaying the Windshear icon on the radar display. New Advisory Alerts are inhibited below 50 ft AGL if airspeed is greater than 100 kts on takeoff, or greater than 60 kts on approach.
- Configuration B:
  No ADVISORY Alerts are shown.

CAUTION ALERTS

The Caution Alert region is ±25° from the aircraft track and from 0.5 nm to 3.0 nm in front of the aircraft.

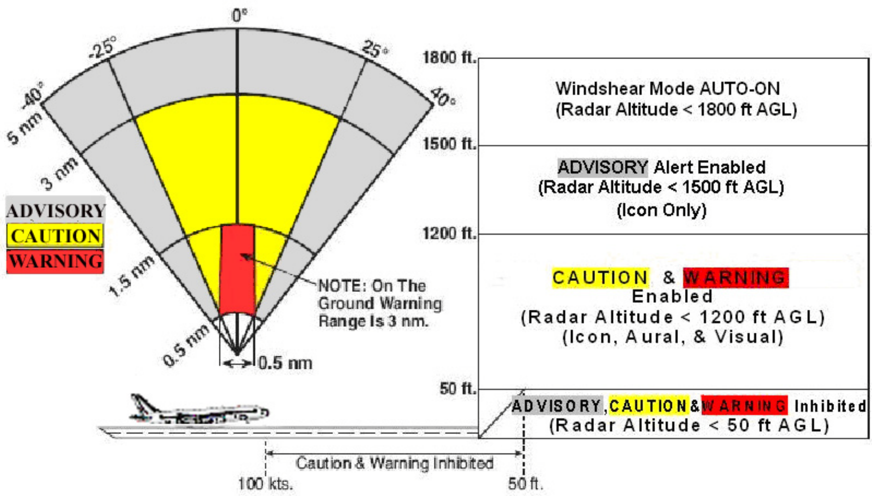
- Configuration A:
  Between 50 ft and 1,200 ft AGL the system indicates CAUTION Alerts with visual and aural annunciations in addition to displaying the Windshear icon(s). New Caution Alerts are inhibited below 50 ft AGL if airspeed is greater than 100 kts on takeoff, or greater than 60 kts on approach.
- Configuration B:
  Between 400 ft and 1,200 ft AGL the system indicates CAUTION Alerts with visual and aural annunciations in addition to displaying the Windshear icon(s). New Caution Alerts are inhibited below 400 ft AGL if airspeed is greater than 80 kts on takeoff, or greater than 60 kts on approach.

WARNING ALERTS

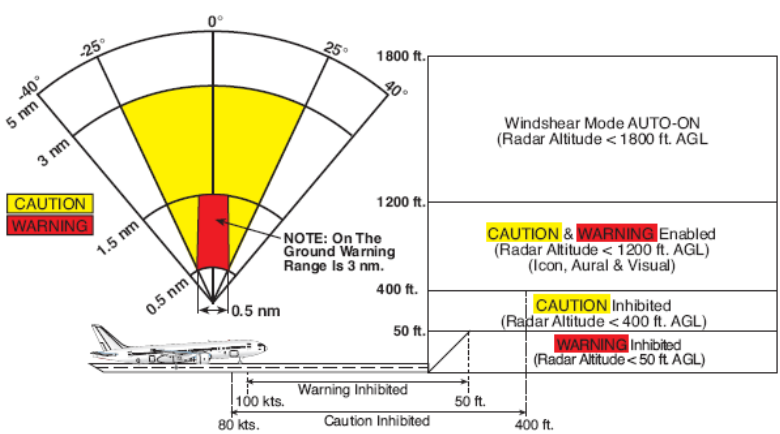
The WARNING Alert region is ±0.25 nm either side of the aircraft track and from 0.5 nm to 1.5 nm (3.0 nm on the ground) in front of the aircraft. On approach below 370 feet, warnings beyond the far end of the runway are inhibited.

Between 50 ft and 1,200 ft AGL the system indicates WARNING Alerts with visual and aural annunciations in addition to displaying the Windshear icon. New Warning Alerts are inhibited below 50 ft AGL if airspeed is greater than 100 kts on takeoff, or greater than 60 kts on approach.

TAKE-OFF ALERT REGIONS

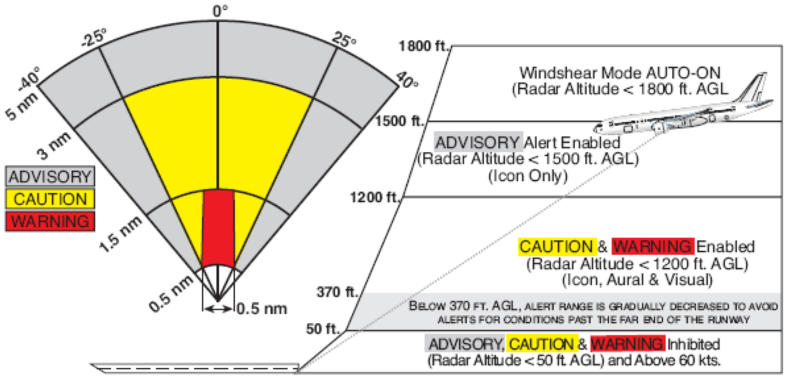


CONFIGURATION A—WINDSHEAR TAKE-OFF
(Includes Advisory Alerts)

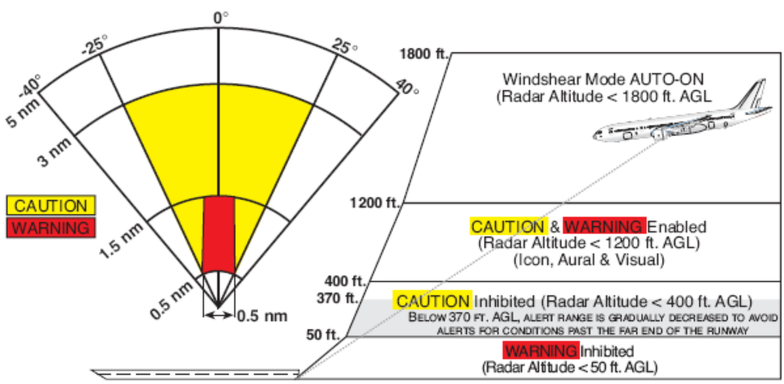


CONFIGURATION B—WINDSHEAR TAKE-OFF
(No Advisory Alerts)

APPROACH ALERT REGIONS



CONFIGURATION A—WINDSHEAR APPROACH
(Includes Advisory Alerts)



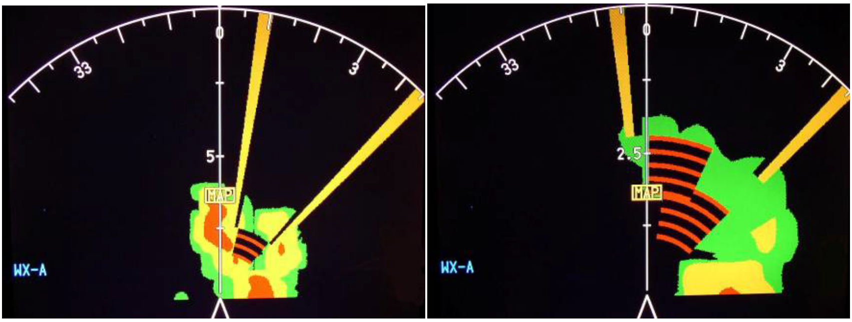
CONFIGURATION B—WINDSHEAR APPROACH
(No Advisory Alerts)

WINDSHEAR ALERT INHIBIT REGIONS

The following table compares the Inhibit Regions of Configuration A and Configuration B (selected during installation).

<table>
<tr><th>Configuration A</th><th>Configuration B</th></tr>
<tr><td>Advisory Alerts are Enabled below 1500 ft.</td><td>No Advisory Alerts</td></tr>
<tr><td>Caution and Warning Alerts are Enabled below 1200 ft.</td><td>Caution and Warning Alerts are Enabled below 1200 ft.</td></tr>
<tr><td colspan="2">Only NEW Alerts are Inhibited as follows. Existing Alerts are not removed.</td></tr>
<tr><td rowspan="2">On Takeoff, All New Alerts are INHIBITED when airspeed is greater than 100 kts if radio altitude is less than 50 ft AGL.</td><td>On Takeoff, New Caution Alerts are INHIBITED when airspeed is greater than 80 kts if radio altitude is less than 400 ft AGL.</td></tr>
<tr><td>On Takeoff, New Warning Alerts are INHIBITED when airspeed is greater than 100 kts if radio altitude is less than 50 ft AGL.</td></tr>
<tr><td rowspan="2">On Approach, All New Alerts are INHIBITED when airspeed is greater than 60 kts if radio altitude is less than 50 ft AGL.</td><td>On Approach, New Caution Alerts are INHIBITED when airspeed is greater than 60 kts if radio altitude is less than 400 ft AGL.</td></tr>
<tr><td>On Approach, New Warning Alerts are INHIBITED when airspeed is greater than 60 kts if radio altitude is less than 50 ft AGL.</td></tr>
</table>

ICON DISPLAY



WINDSHEAR ICONS WITH SEARCH LINES

The Windshear icon shown on the display represents the location of the event in both range and azimuth. In the left example, the windshear event begins about 2 nm ahead and 25° to the right of the aircraft. The example on the right shows two icons, indicating two windshear events. The yellow and black search-lines help locate the icon in case a long range is selected.

VISUAL PWS ALERT ANNUNCIATIONS

Visual Caution and Warning Alerts are annunciated on the Electronic Displays.

- **Caution Visual Alert:** Amber “WINDSHEAR”
- **Warning Visual Alert:** Red “WINDSHEAR”

AURAL PWS ALERT ANNUNCIATIONS

Caution and Warning Alerts are generated by the cockpit audio system.

Caution Aural Alerts may be one of the following (selected at installation):

- Option 1: “Whoop, Whoop”
- Option 2: “Monitor Radar Display”

Warning Aural Alerts are as follows:

- Take-Off: “Windshear Ahead, Windshear Ahead”
- Approach: “Go Around, Windshear Ahead”

PWS SYSTEM FAILURE ANNUNCIATION

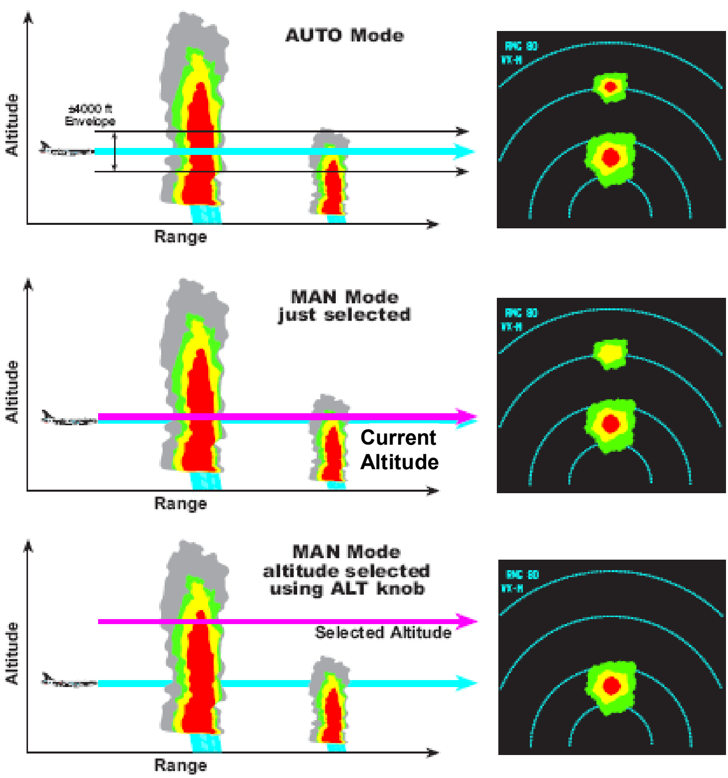
System failures are annunciated on the Electronic Displays. Examples: NO PWS, PWS INOP, or W/S PRED

WEATHER ANALYSIS

MANUAL WEATHER MODE

Manual Weather Mode provides a means to assess storm cell height and development by providing selectable altitude slices. These slices from the 3D memory are corrected for the curvature of the earth, providing a view at a constant MSL altitude level.

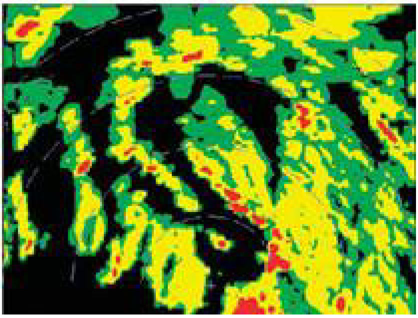
Selecting MAN on the mode selection knob enters the Manual Mode. Upon initial selection, the altitude slice is set to the current aircraft altitude (nearest 1000 feet). The altitude (ALT) knob is used to select the desired altitude slice from 0 to 60,000 feet MSL in 1,000 foot intervals. If the Hazard Display features are installed, Hail and Lightning icons and REACT fields will be displayed and detected turbulence will be shown out to 60 nm, as appropriate to the selected altitude.



FULL COVERAGE GROUND MAP MODE (MAP)

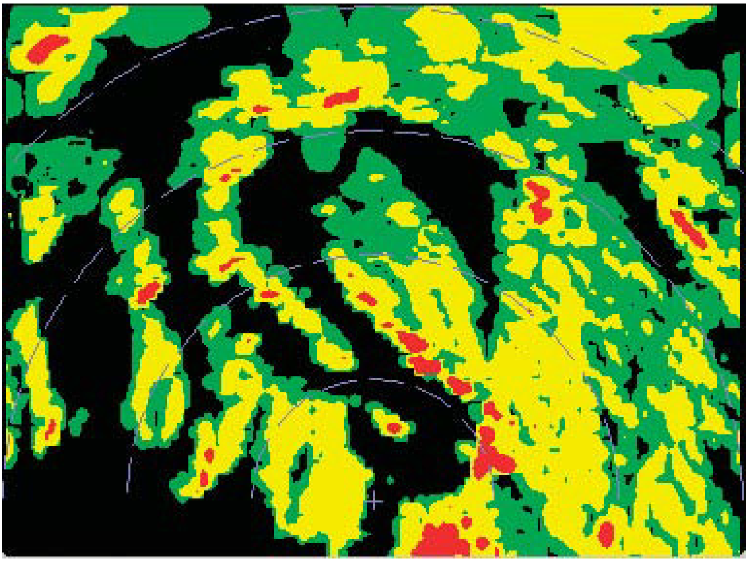
The RDR-4000 Weather Radar System can be used in Ground Map mode to identify terrain features. For ground mapping use the following procedure:

1. System Control: L/R (or NORM)
2. Mode: MAP
3. Range: As desired
4. Gain: If necessary, adjust for optimum observation of terrain features.



The purpose of the MAP mode is to aid in identifying prominent terrain features, such as coastlines, lakes, and large built-up urban areas. MAP mode provides an extended ground map picture by piecing together individual scans and combining them in the memory for display. Reflectivity data that is considered ground clutter (and removed from the weather views) is the basis for the Ground Map. Data from the topography database is not used, providing an independent verification of position. The Ground Map is generated automatically and simultaneously with weather.

See the following pictures for a comparison of a MAP display and a satellite photo of the same area.

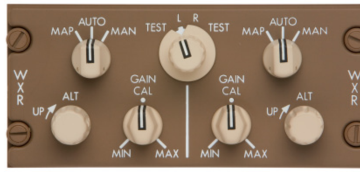


RDR-4000 SEATTLE AREA MAP DISPLAY

SEATTLE AREA SATELLITE IMAGE

(Picture from earth.google.com)

GAIN CONTROL (GAIN)



GAIN control is active in all modes except TEST. The calibrated (CAL) position is the same as AUTO gain mode and is the only position where the colors represent the FAA defined reflectivity and rainfall rates as shown in the table below. The CAL gain setting provides a standard reference which all radar manufacturers must follow. Immediately after turning the GAIN control in either direction out of the detent position (CAL), the “VAR” annunciation appears on the display indicating that the system is no longer in the calibrated mode. Rotating the GAIN control counterclockwise decreases gain; rotating the GAIN control clockwise increases gain. The gain setting has no effect on turbulence detection or display. After using the GAIN control to assess weather it should be returned to the CAL position.

If the Hazard Display Configuration of the radar system is installed, the GAIN knob can also be used to temporarily suppress the display of Hazard Icons and Turbulence Indication. See HAZARD DISPLAY SUPPRESSION on page 29 for details.

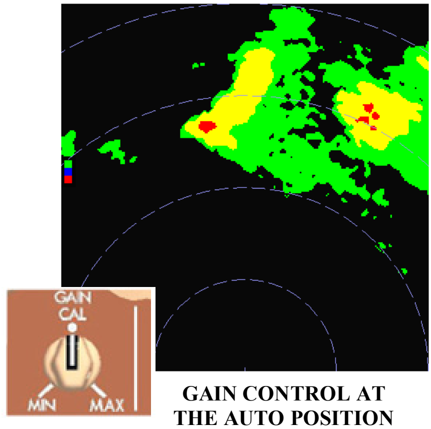
Reflectivity Color Codes (Gain at CAL)

Color	Returns	Reflectivity	Rainfall Rate
Black	Very light or none	Less than 20 dBz	Less than 0.7 mm/hr (0.028 in/hr)
Green	Light	20 – 30 dBz	0.7 – 4 mm/hr (0.028 – 0.16 in/hr)
Yellow	Medium	30 – 40 dBz	4 – 12 mm/hr (0.16 – 0.47 in/hr)
Red	Strong	40 dBz or greater	Greater than 12 mm/hr (0.47 in/hr)
Magenta	Turbulence	N/A	N/A

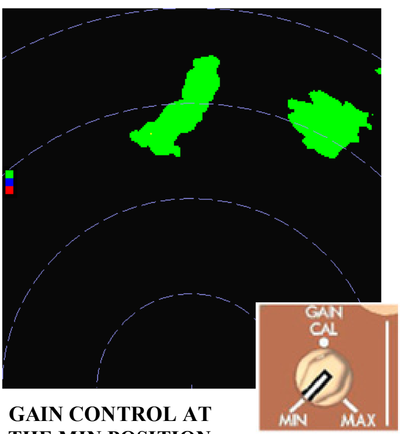
In all modes except TEST, rotating the GAIN Knob to the minimum (MIN) position reduces gain by approximately 16 dBz. Rotating the GAIN Knob to the maximum (MAX) position increases gain by approximately 10 dBz.

Proper use of the gain control can aid in the detection and assessment of storm cells. Gain reduction can be useful in several ways. Reducing the gain to MIN provides a quick assessment of the relative intensity between displayed cells. Since gain does not affect turbulence detection, reducing gain in the AUTO mode to MIN will show turbulence information along with the strongest cells. This is important since the presence of turbulence along with high levels of reflectivity often indicates convective weather. In areas of heavy stratus rain, the display can show large areas of strong returns, but with little associated turbulence.

Reducing the gain can also help identify embedded storm cells within the stratus rain. It can help identify areas of significant attenuation by making radar shadows more prominent. Areas of missing terrain returns in MAP mode that correspond with strong weather echoes may indicate a larger area of precipitation than is apparent on the weather display. (See SHADOWED AREAS on page 45.)



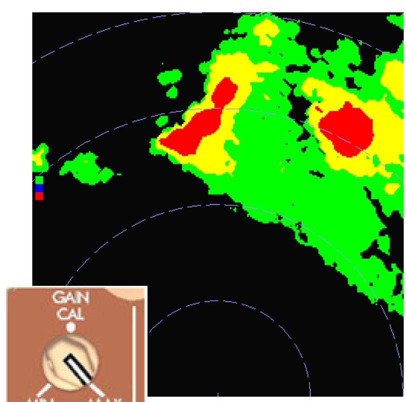
GAIN CONTROL AT THE AUTO POSITION



GAIN CONTROL AT THE MIN POSITION

Use MAX gain only when at cruise altitudes. In MAN mode, MAX gain is useful when looking at altitude slices above the freezing level where particles are less reflective. High levels of moisture above the freezing level are key ingredients in hail formation.

Increase the gain briefly at any altitude to discover the relative reflectivity of a weather formation that is visible out the window but does not initially appear on the display. This occurs when the reflectivity of the cloud is below the standard threshold for green weather.



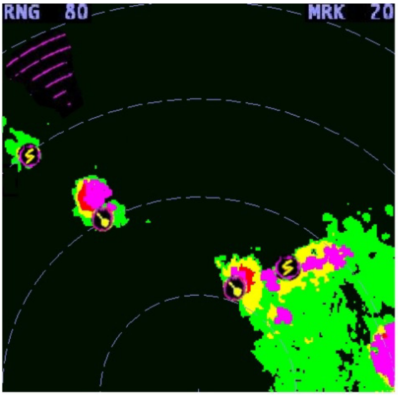
GAIN CONTROL AT THE MAX POSITION

HAZARD DISPLAY SUPRESSION

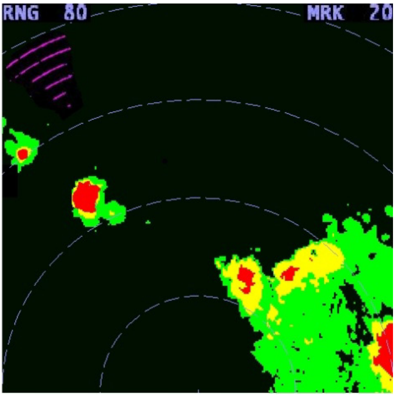
If the Hazard Display Configuration of the radar system is installed, it may occasionally be desirable to suppress the display of Turbulence, Hail Icons, and Lightning Icons in order to view the underlying reflectivity levels.

To suppress the display of the Hazard Indications:

- In AUTO or MAN mode, rotate the GAIN knob out of the CAL position and then back to CAL to suppress the hazard icons and turbulence indications for approximately 15 seconds.
- If you use the GAIN knob to go to variable gain (VAR), the hazard icons and turbulence indications will be suppressed for about 15 seconds after the last adjustment of the GAIN knob, and then restored.
- If you are already in variable gain (VAR) and wish to temporarily suppress the display of the hazard indications, simply turn the GAIN knob to CAL, and then back to the desired gain setting.
- If you switch to the AUTO or MAN mode while using a variable gain setting (VAR), the hazard icons and turbulence indications will be suppressed for approximately the first 15 seconds after entry into the new mode, and then restored.
- The display of REACT and PWS Icons is not affected.
- Note that prolonged use of VAR gain is not recommended.

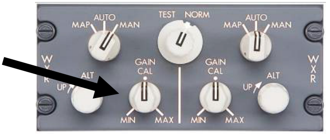


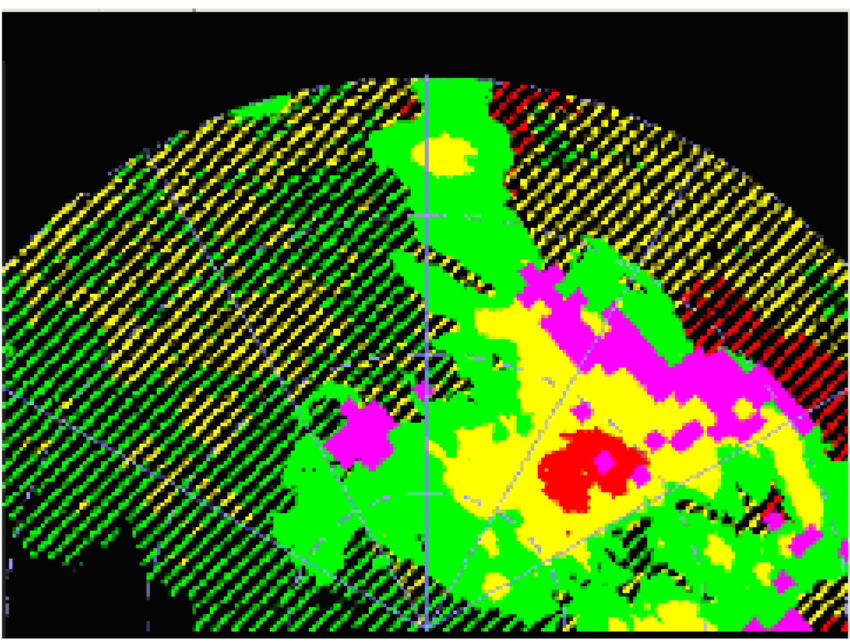
Before Icon Suppression



After Icon Suppression

To temporarily suppress icons and turbulence indications, move GAIN control momentarily out of CAL position, and then back.





SECTION 4: EQUIPMENT DESCRIPTION

UNIT DESCRIPTIONS

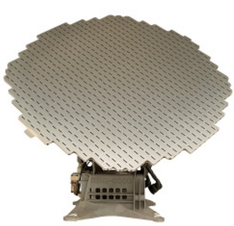
RP-1 RADAR PROCESSOR

The Radar Processor contains the electronics necessary to process the radar data received from the transmitter/receiver, control the modes of the radar and to format the radar data for display. The RP-1 is normally located in the Forward EE-Bay.

TR-1 TRANSMITTER/RECEIVER

The Transmitter/Receiver contains the electronics necessary to transmit, receive, and process the radar pulses used to detect turbulence, windshear, weather, and terrain targets. It also contains the system integrity monitoring and self test electronics. The TR-1 is located in the radome in the base of the antenna drive.

DA-1A/B WITH FP30-1 ANTENNA DRIVE



The component parts of the antenna drive are the DA-1A (single) or DA-1B (dual) Antenna Drive and the FP30-1 flat-plate array. The antenna drive, located within the radome, forms the microwave energy into a 3 degree beam. The antenna also receives the return microwave energy, after reflection by weather formations or other objects, and routes these signals to the transmitter/receiver for processing. The antenna drive scans a 160 degree sector in azimuth and ±15 degrees in elevation (tilt).

CP-1A/1B CONTROL PANELS

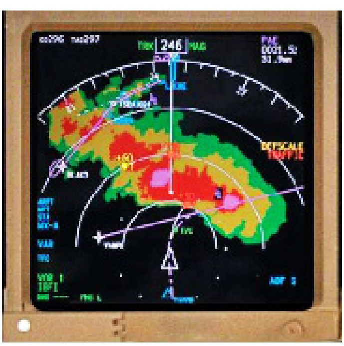
CP-1A

CP-1B

The CP-1A/1B contains all controls for operating the radar system except those located on display units or electronic flight display control panels. The CP-1A is used in a single system configuration while the CP-1B is the dual system control panel.

The RDR-4000 has the ability to show two different radar display views simultaneously. The left side of the control panel controls the left side display (Captain) and the right side of the control panel controls the right side display (First Officer). The flight crew can operate each side independently without impacting radar performance, achieving maximum weather information display.

ELECTRONIC FLIGHT DISPLAY



The Electronic Flight Display is not part of the RDR-4000 system, but is where the radar mode or status, weather returns, windshear, turbulence, and ground map data are displayed. This picture is intended as an example only. Your equipment may vary.

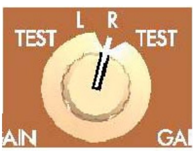
The Electronic Flight Display Control Panel is not part of the RDR-4000 system, but is used to select Weather Radar (WXR) for display. This picture is intended as an example only. Your equipment may vary.

OPERATING CONTROLS

When WXR is not selected on the display system, no radar display is shown. While in the air, or on the ground if the radar has been auto-activated by qualifiers, the radar will nevertheless continue to operate, constantly updating the 3D memory so that current radar data is immediately available whenever WXR is selected. (Typical auto-activation qualifiers are Engine at Take-Off Thrust Setting, or both Oil Pressure Active and Transponder On, or the Runway Awareness Advisory System (RAAS) – if installed, indicates "On Runway". See AUTOMATIC WINDSHEAR ACTIVATION on page 18.)

When approaching a gate, deselect WXR on all displays and/or select TEST on the control panel to prevent the radar from transmitting.

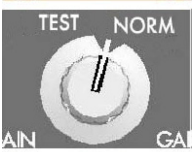
SYSTEM CONTROL



(CP-1B)

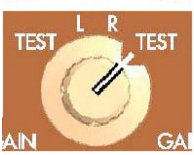
L: Selects left system for normal weather operation.

R: Selects right system for normal weather operation.



(CP-1A)

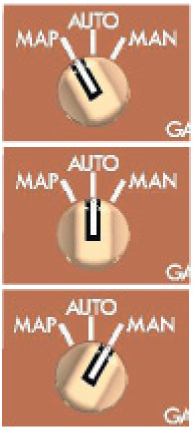
NORM: Normal weather operation.



(CP-1A/CP-1B)

TEST: Selects test mode and provides a test pattern to allow verification of system operation and fault isolation. While on the ground, the system test will also exercise the windshear aural and visual alerts shortly after being selected. If the system control is placed in TEST while in flight, the display will show the test pattern, but no windshear aural or visual alerts will be annunciated. If a windshear event is detected while in the test mode, the display will switch to weather with the windshear icon overlaid, and warning or caution annunciations will be triggered, as appropriate.

MODE SELECTION

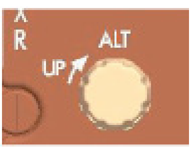


MAP – Displays Full Coverage Ground Map

AUTO – Automatic Weather Presentation Mode Provides detection of windshear out to 5 nm. It displays turbulence out to 40 nm and weather out to 320 nm. Secondary weather returns are shown with black stripes through them. If Hazard Display is installed, turbulence is extended to 60 nm, and lightning, hail, and REACT indications are shown.

MAN – Manual Constant Altitude (Weather Analysis) mode. The altitude slice defaults to current altitude upon MAN selection. Provides detection of windshear out to 5 nm and displays weather out to 320 nm. If Hazard Display is installed, turbulence is shown out to 60 nm, and lightning, hail, and REACT indications are shown.

MANUAL ALTITUDE CONTROL



ALT – Controls weather analysis altitude from 0 to 60,000 feet MSL in increments of 1000 feet. Selected altitude is shown on the Electronic Flight Display.

GAIN CONTROL

CAL – Rotate to the CAL position for automatic gain control. The CAL position results in a calibrated map or weather radar display. Gain control does not affect turbulence or windshear.

Manual – Rotating knob out of CAL varies gain between MIN and MAX. VAR is shown on the display, indicating that the gain has been changed from the calibrated position.

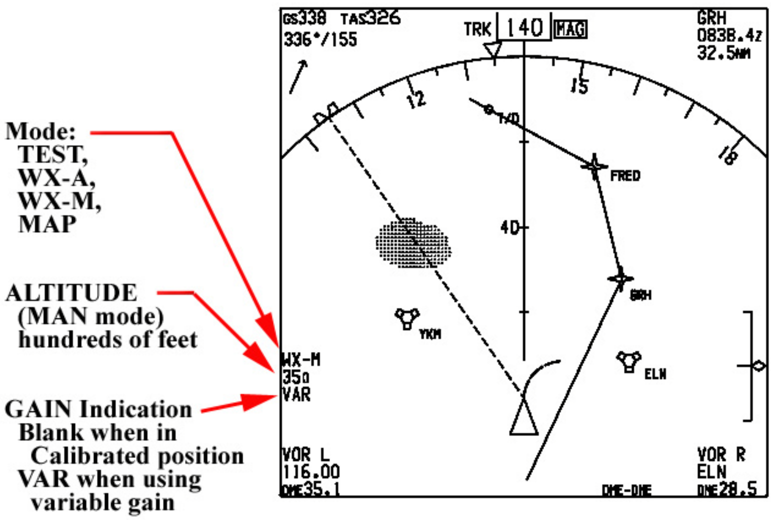
The **MIN** position reduces gain approximately 16 dBz below the CAL setting;

The **MAX** position increases gain 10 dBz over the CAL setting.

If the Hazard Display Configuration of the radar system is installed, the GAIN knob can also be used to temporarily suppress the display of Hazard Icons and Turbulence Indication. See HAZARD DISPLAY SUPPRESSION on page 29 for details.

DISPLAY ANNUNCIATIONS

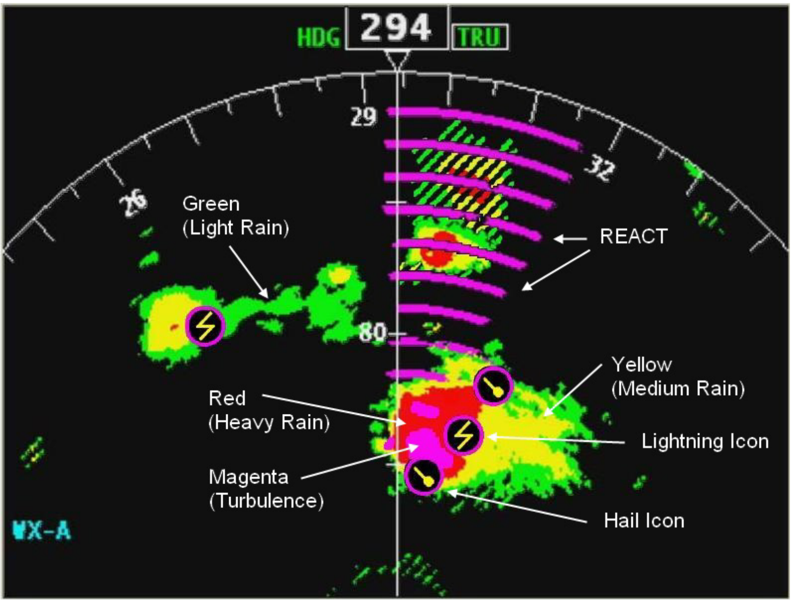
Actual annunciations are display dependent. The following figures are provided as examples only.



WEATHER RADAR DISPLAY ANNUNCIATIONS - EXAMPLE.

WEATHER RADAR DISPLAY - EXAMPLE

DISPLAY COLORS



WEATHER RADAR DISPLAY COLORS
(Some features will not be available in all installations)

FAULT ANNUNCIATIONS

Fault annunciations alert the pilot that the radar system is not performing to established standards. Built-in test equipment (BITE) automatically and constantly tests the radar system. If a system failure occurs when operating in any mode other than TEST mode, a generic WXR FAIL message will be annunciated on the display. If this should occur, select the TEST mode to confirm the fault and to see more information about the failure. This test may be run either on the ground or in the air. It will take less than a minute to run. If a fault is confirmed, the cause of the fault will be annunciated on the display as explained below.

If a system failure is detected when in the TEST mode, the test pattern will be replaced by the name of the unit in which the failure occurred. Failures will appear as yellow caution annunciations on the display. Some faults will cause any displayed radar data to disappear entirely, while others overlay the radar display.

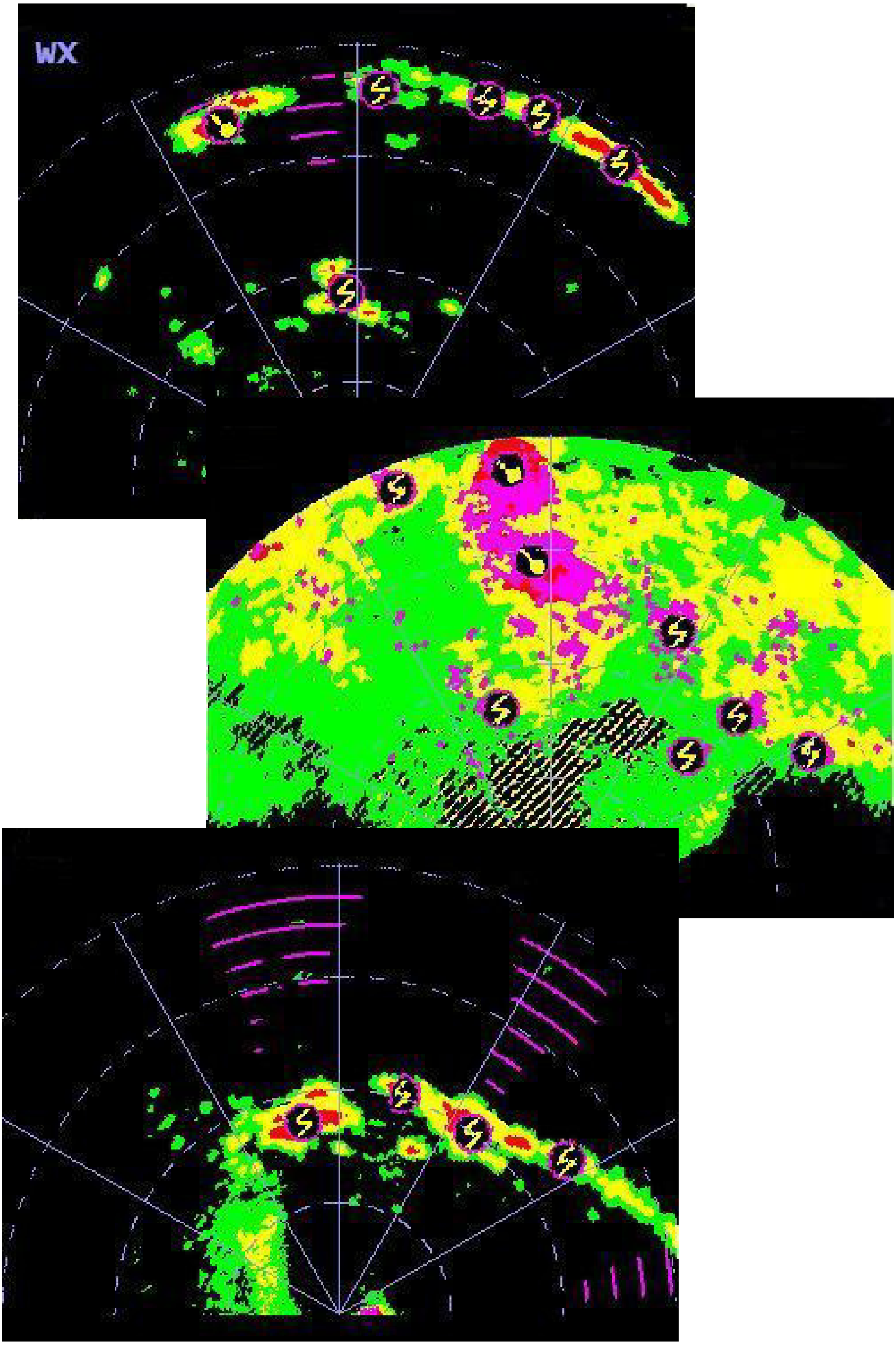
If the fault does not resolve itself shortly, try cycling power to the system. In a dual installation select the other system. If none of these actions correct the problem, turn off power to the system.

The following table shows some typical fault annunciations. Actual fault annunciations depend upon the display in use.

Example of Fault Annunciations

Display Annunciation	Failure
RT	Transmitter/Receiver (TR-1) Unit Failure
ANT	Antenna Drive Failure
CONT	Control Panel Fault
WEAK	TR Unit Fault - Below Normal Power
PROC	Radar Processor (RP-1) Fault
ATT	Attitude Fault

See the aircraft installation documentation for complete descriptions of the possible failure modes.


WX

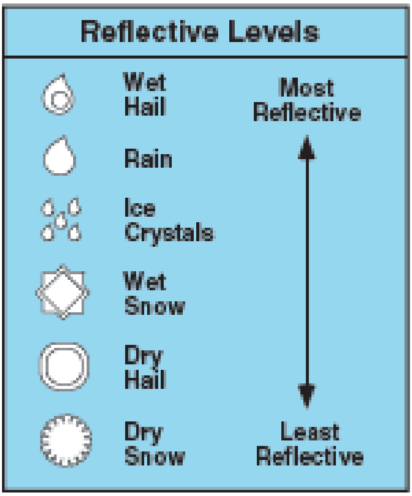
SECTION 5: PRINCIPLES OF WEATHER RADAR USE

WEATHER RADAR PRINCIPLES

Airborne weather avoidance radar, as its name implies, is for avoiding severe weather - not for penetrating it. Whether to fly into an area of radar echoes depends on echo intensity, spacing between the echoes, and the capabilities of both pilot and aircraft. Remember that weather radar detects only precipitation; it does not detect minute cloud droplets. Therefore, the radar display provides no assurance of avoiding inclement weather in clouds and fog. Your display may be clear between intense echoes; this clear area does not necessarily mean you can fly between the storms and maintain visual separation from them.

Weather radar detects droplets of precipitation size. The strength of the radar return (echo) depends on drop size, composition, and amount of water. Water particles return almost five times as much signal as ice particles of the same size. This means that rain is more easily detected than snow, although at times large, wet snowflakes may give a strong return.

Hail usually has a film of water on its surface; consequently, a hailstone is often reflected as a very large water particle. Because of this film and because hailstones usually are larger than raindrops, thunderstorms with large amounts of wet hail return stronger signals than those with rain. Although wet hail is an excellent reflector of radar energy, some hail shafts are extremely small (100 yards or less) and make poor radar targets. If hailstones are cold and dry, they give poor returns and might not appear on the display.

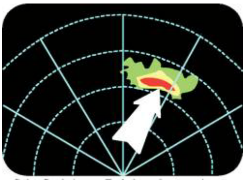


STORM CELL CHARACTERISTICS

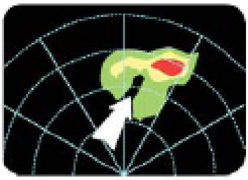
CONVECTIVE WEATHER

Airborne weather radar allows pilots to identify and avoid potential weather hazards. The radar performs signal processing to estimate the radar reflectivity of the weather ahead. Reflectivity can be correlated to precipitation rate, and is displayed as green (light), yellow (moderate), and red (heavy) precipitation.

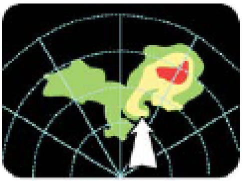
Reflectivity is used to identify the presence of potentially hazardous weather. However, reflectivity alone should not be used to determine the degree of hazard. Pilots should use the displayed reflectivity to recognize weather features that can indicate potentially hazardous conditions.



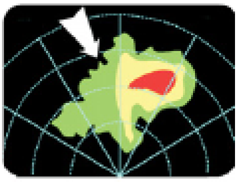
For example, a tight gradient (rapid transition of color levels with distance) in the reflectivity field is usually associated with severe turbulence generated by vigorous convection and should be avoided. Other shapes are strong indicators of the presence of hail, such as:



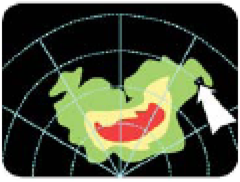
U-SHAPE



FINGER



SCALLOPED EDGE



HOOK

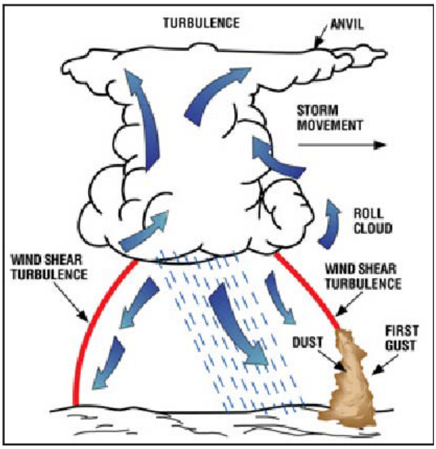
Weather hazards that can be identified by the use of radar are generally associated with convective storms. Convection results in towering storm structures that can contain high wind gradients that lead to turbulent motion. Very vigorous convection can generate severe turbulence in the vicinity of the high reflectivity core, downwind of the core, and at the top of the storm. The strength of the convection can be judged by the vertical size of the convective cell and the extent of high reflectivity portions of the storm, as well as the presence of shapes described above. At ranges less than 40 nautical miles (or 60 nm if the Hazard Display features are installed) the display of magenta will indicate areas of particularly turbulent activity.

If the Hazard Display features are installed, hail or lightning icons will automatically identify areas where those hazards are likely to occur, and the display of turbulence is extended to 60 nm.

Convective weather is associated with hazards due to turbulence, hail, and lightning strike. Recognizing convective weather is instrumental in avoiding these hazards.

STRATIFORM WEATHER

In addition to reflectivity associated with convective weather, the radar will typically display reflectivity associated with stratus, or stratiform, weather. Whereas convection is characterized by localized towers of updraft and downdraft features, stratiform precipitation results from much more widespread and much less vigorous uplift. As a result, stratus precipitation is more layered in form with much lower gradients in radar reflectivity. However, reflectivity of stratiform weather can be sufficient to cause yellow and red on the radar display. These high reflectivities result from relatively high rain rates, as well as from enhancement of reflectivity due to melting of snow particles just below the freezing level. High reflectivity of stratus weather does not indicate any significant hazard (with the exception of any potential for icing, or takeoff and landing performance issues associated with high rainfall rates). Therefore, it is important that pilots be able to recognize hazards based on the form of the weather (convective versus stratiform) and the other considerations described above, not by observing the reflectivity level alone.



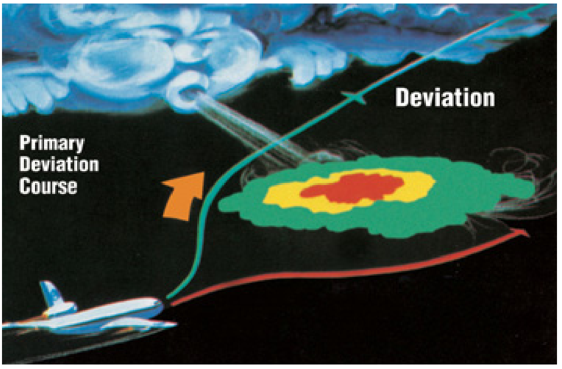
ICING

Updrafts in thunderstorms support abundant water; when carried above the freezing level, this water becomes supercooled. As the temperature in the upward current cools to about -15°C, much of the remaining water vapor sublimates as ice crystals. Above this level, the amount of supercooled water decreases.

Supercooled water freezes on impact with an aircraft. Clear icing can occur at any altitude above the freezing level; but at high levels, icing may be rime or mixed rime and clear. The abundance of supercooled water makes clear icing occur very rapidly between 0°C and -15°C, and encounters can be frequent in a cluster of cells.

PLANNING A PATH

Remember to plan a deviation path early. Simply skirting the red or magenta portion of a cell is not enough. Wherever possible, plan an avoidance path for all weather echoes which appear beyond 100 nm since this indicates they are quite dense. If a REACT field is shown, plan to avoid that area since there may be weather there that the radar cannot detect. Refer to the FAA Approved Airplane Flight Manual and to the FAA Advisory Circulars referenced on page 3 for detailed information on flying in the vicinity of and avoiding thunderstorms and turbulence.



PLAN A WEATHER AVOIDANCE PATH IN ADVANCE

The most intense echoes indicate severe thunderstorms. Remember that hail may fall several nautical miles from the cloud, and hazardous turbulence may extend as much as 20 nautical miles from the cloud. You should avoid the most intense echoes by at least 20 nautical miles, if possible. If the Hazard Display features are installed, avoid areas with hail or lightning icons by a similar distance. As echoes diminish in intensity, you can reduce the distance by which you avoid them.

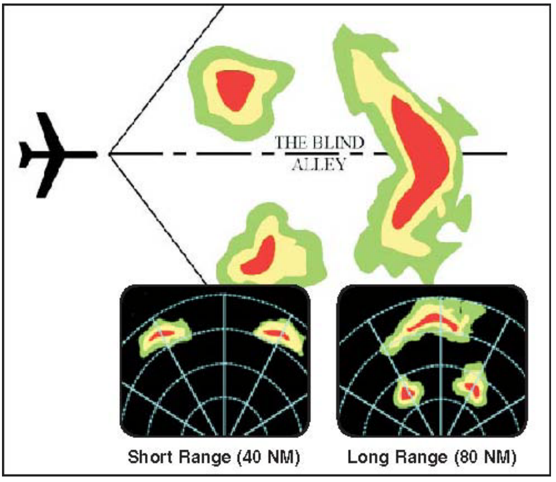
The lightning and hail icons provide additional clues as to whether reflectivity indications are associated with convective developments and provide an indication that the convection may be generating hail and/or lightning. As with any weather radar system, the crew must integrate all possible information including information from sources other than weather radar such as forecast conditions, PIREPs, ground based weather systems and Air Traffic Control when making deviation and penetration decisions.

Also, note that by definition Clear Air Turbulence is always possible in areas of no displayed reflectivity.

PATH PLANNING CONSIDERATIONS

- Where possible, any indicated reflectivity should be avoided
- Reflectivity may generally be penetrated if the crew is sure that the reflectivity is associated with stratus (non-convective) rainfall
  - Stratus rainfall is characterized by widespread, relatively uniform reflectivity, with tops often below 25,000 ft, and with little or no indication of turbulence
- Weather with tall vertical development (as can be determined using the manual mode), indications of turbulence, lightning, and/or hail should be considered convective and should be avoided
- Hail and lightning icons identify which cells are likely producers of the associated hazard, but do not explicitly detect the present location of the hail or the lightning. Since lightning and hail can extend a significant distance from the core of the cell, the entire cell should be considered as containing the hazard
  - Icons are generally placed on the display at or near the center of the area where the hazard-producing convection is located. It is possible that a single icon could indicate the presence of a number of separate hazardous convective cells in order to avoid display clutter. To better resolve the individual convective cells with hazards associated, select a lower display range. It is possible for an icon to appear to have no reflectivity displayed in association with it. However, in this case it should be assumed that the associated convective cell is covered by the icon, and the presence of the hazard in the vicinity of the icon must be assumed.
- Cells with hail icon indications should be assumed to also be producers of lightning
- Convective cells should be avoided by 20 nm. Characteristics of convective cells include one or more of the following:
  - Cells with large vertical structure (as can be determined using the manual mode)
  - Hail icons
  - Lighting icons
  - Turbulence indications
- For a build-up of scattered cells where it may not be practical to observe the 20 nm avoidance guideline, plan a path upwind of the cells with the lesser hazard while avoiding other cells by 20 nm. Avoid penetrating any areas with REACT indications.
  - Generally, consider cells with any magenta turbulence and hail icons as the most hazardous cells, then in order of decreasing severity:

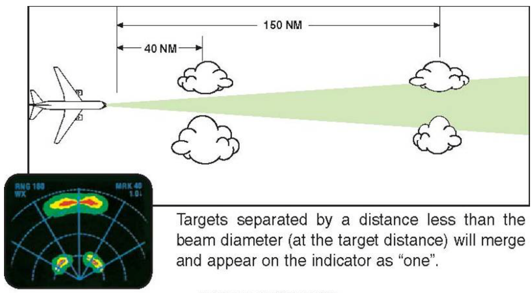
  - Cells with turbulence and lightning indications (no hail indications)
  - Cells with no hazard icon, but with turbulence indicated.
  - Cells with reflectivity only, with maximum reflectivity of red
  - Cells with reflectivity only, with maximum reflectivity of yellow
  - Cells with reflectivity only, with maximum reflectivity of green
- If a squall line or system of cells must be penetrated, plan a path through the weather in a region of the least indicated hazard with the lowest reflectivity, generally staying upwind of the most severe hazards. Avoid penetrating any areas with REACT indications.
- A "Blind Alley" or "Box Canyon" situation can be very dangerous. When viewing the short ranges, periodically switch to longer-range displays to observe distant conditions. In the example shown to the right, the short-range returns show an obvious corridor between two areas of heavy rainfall but the long-range setting shows a larger area of heavy rainfall.



- Thunderstorms build and dissipate rapidly. Therefore, you SHOULD NOT attempt to pre-plan a flight plan course between closely spaced echoes, or under or over convective cells. Avoid individual storms in flight either by visual sighting or by use of airborne radar.

AZIMUTH RESOLUTION

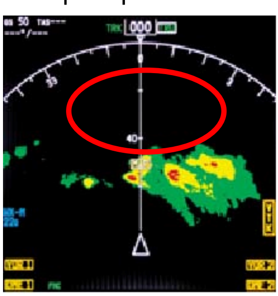
Azimuth resolution is a function of the beam width. When two targets are closely adjacent in azimuth and at the same range, the radar may display them as a single target. However, as the targets are approached they appear to separate. The ability of the radar system to resolve these targets is a function of the antenna's beam width and the range to the target.



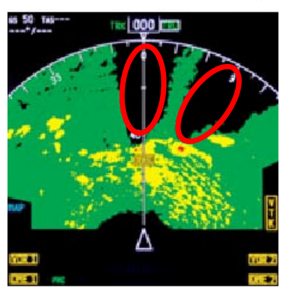
AZIMUTH RESOLUTION

SHADOWED AREAS

Extremely heavy rainfall or high terrain can reduce the ability of the radar to penetrate and present a full picture of the weather area. This is called "radar attenuation". If the Hazard Display features are installed, a REACT field will indicate attenuated areas. Otherwise, use MAP mode along with the weather modes to identify areas of shadowing. Observe the ground returns in the area behind the strong weather echo. With very heavy intervening rain, the ground returns behind the echo will not be present but rather will appear as a shadow. This may indicate a larger area of precipitation than appears on the weather display.



Weather display. Note the area of apparent clear weather behind the storm cells. If the MAP 1 display shows a shadow in this area, there may be weather here that the radar cannot see.



Corresponding MAP display. The lack of radar returns in the circled areas indicates that terrain or very heavy rain in front of those areas prevents the radar signal from penetrating any farther.

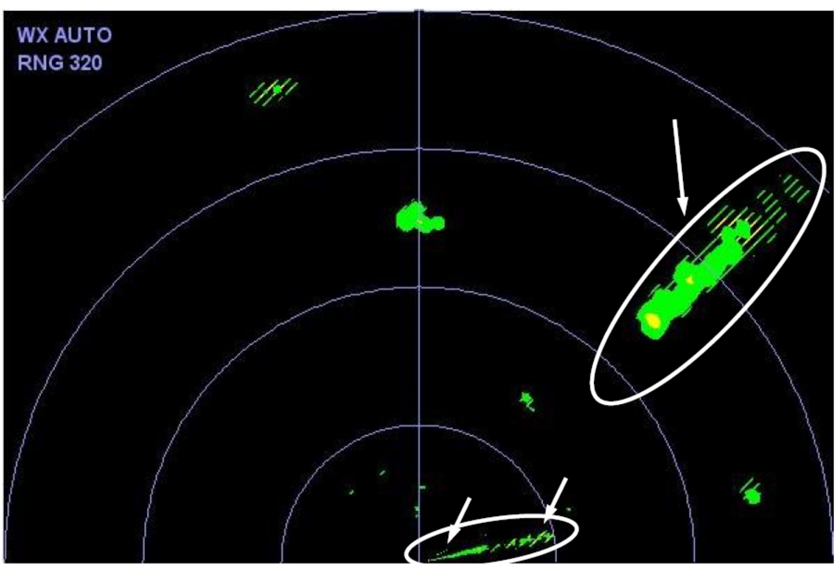
EFFECTS OF INTERFERING RF SOURCES

An interfering radio frequency (RF) source operating at a frequency close to the radar's operating frequency can create unusual returns on the display. These returns are caused by Continuous Wave (CW) sources of RF radiation. The interference may appear as occasional isolated dots, or as radial spikes of any color (including magenta) on the display. Algorithms in the software suppress most of these returns, but they cannot always be completely suppressed. Once the source of interference is no longer active, the spots will typically be removed after the antenna re-scans the area and updates the memory; approximately thirty seconds.

CW RF sources that can cause this effect include:

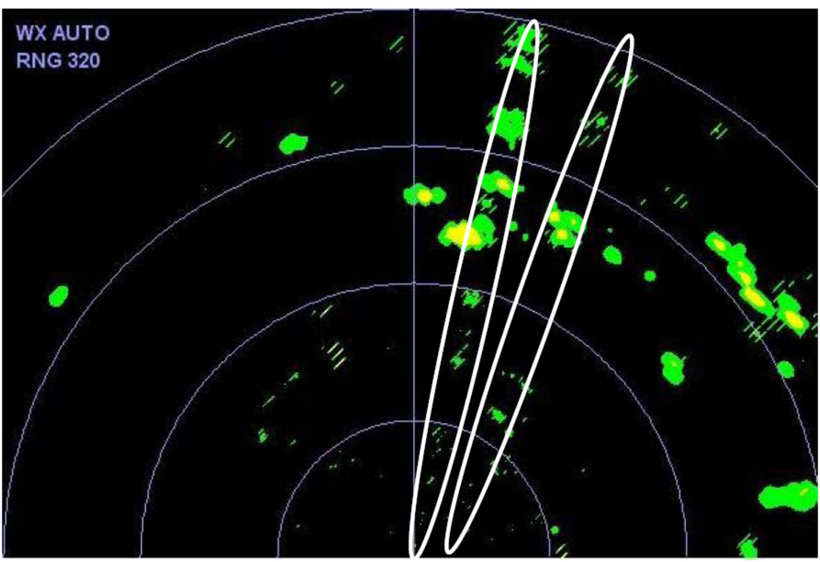
- CW Military Radar
- Radar Jamming Equipment
- Satellite Uplink Equipment

Adjusting the manual gain may help alleviate the effect of the interfering source but the effect will not completely disappear until the interfering source is no longer in the radar's field of view and that area of the memory has been refreshed.



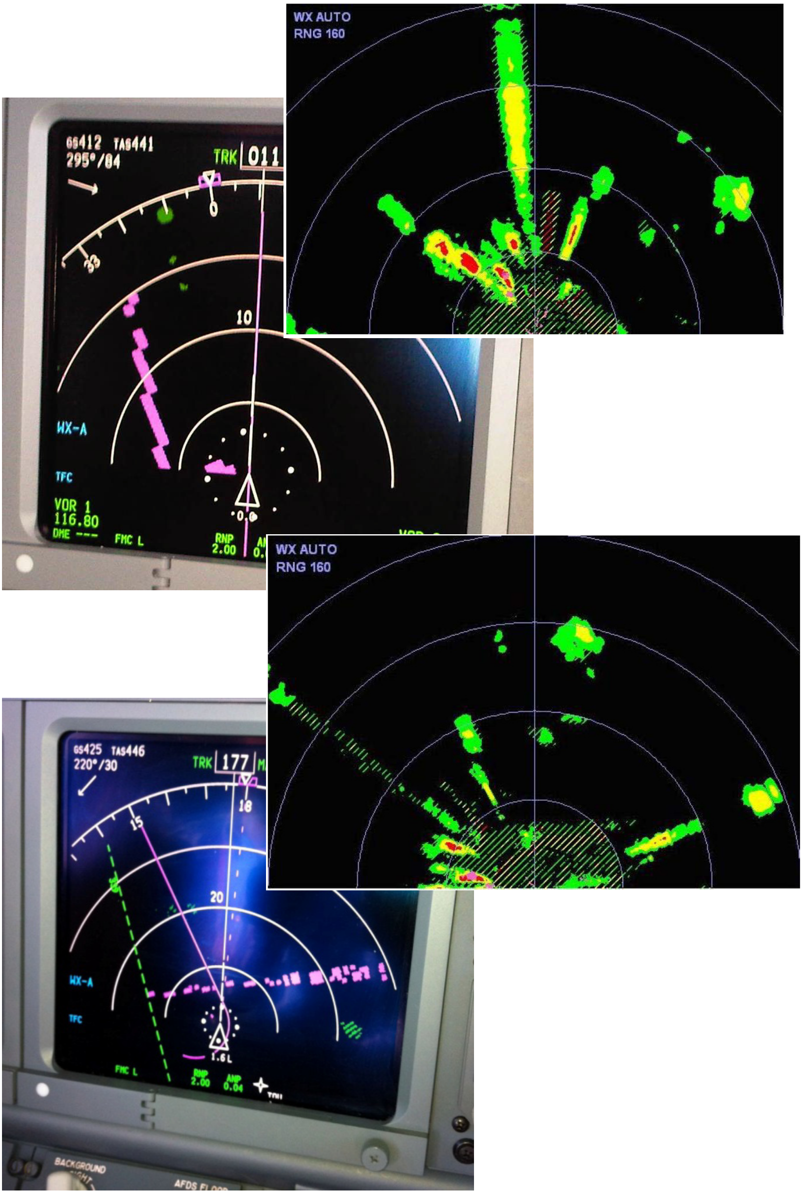
In the above picture, there are at least three sources of interference, at different frequencies.

This figure shows a zoomed-in view of the near-range interference from the previous figure.



In this figure, the interference is a bit more subtle, as it is mixed in with real weather. However, a close look reveals several radial spokes. The two most obvious ones have been circled.

These figures show more examples of RF interference.



RADAR WINDSHEAR DETECTION

During both takeoff and landing, microbursts have been the cause of numerous transport aircraft accidents.

WINDSHEAR/MICROBURST DESCRIPTION

A microburst is a cool shaft of air, like a cylinder, between ½ and 1½ nm across that is moving downward. When it encounters the ground, the air mass mushrooms in a horizontal direction curling inward at its edges. The downward air velocities associated with these narrow air shafts range from 20 to 40 knots.

Two types of microbursts exist; wet and dry. In a wet microburst, rain droplets within the airshaft fall largely intact all the way to the earth's surface. This type of event is typical of humid areas like the southeast United States. A dry microburst may contain virga, or rain that exits from the cloud base, but mostly evaporates before reaching the ground. Virga occurs in high-based rainstorms found in places like the high plains and western United States. Regardless of whether the microburst is wet or dry, the airshaft's wind characteristics are identical.

When the downward moving airflow becomes a horizontal flow at the base of the airshaft, the outflow winds have front-to-back velocities ranging from 20 to 80 knots.

WINDSHEAR/MICROBURST DETECTION PROCESS

When the airshaft of a microburst encounters the ground, it mushrooms outward carrying with it a large number of raindrops. By measuring the horizontal velocity of these water droplets the RDR-4000 is able to infer the horizontal and vertical velocity of the winds carrying the raindrops.

The radar processor detects the Doppler frequency shift imparted onto the reflected microwave pulses by a microburst. As the radar scans across the windshear event, it will detect raindrops moving toward it at one range and away from it at a slightly greater range.

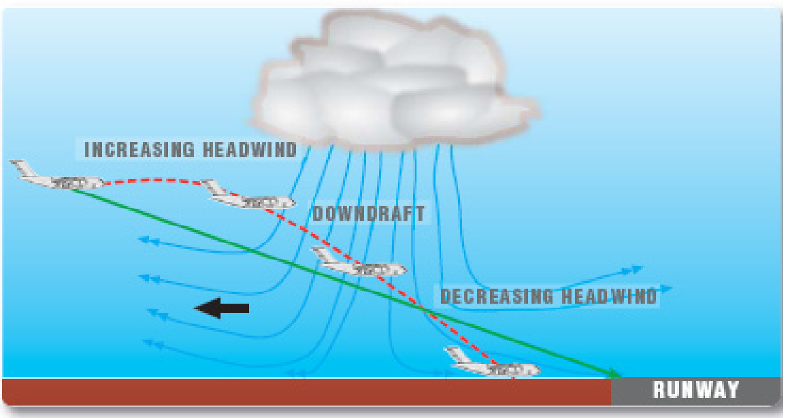
The difference in the range between the raindrops moving toward and away is the width of the base of the microburst. After the radar detects this condition, it then proceeds to assess the severity of the event by measuring how fast the droplets are moving. If the assessment of the severity of the micro-burst exceeds a preset threshold value, a windshear alert is issued on the radar display and through the flight deck audio system.

The RDR-4000 has the ability to detect the presence of microbursts up to 5 nm ahead of the aircraft when below 1800 feet AGL.

WINDSHEAR AVOIDANCE FLYING

The air shaft of a microburst creates problems for aircraft for two reasons. The first problem is due to the downward air movement. Since the aircraft is flying within the air mass, as the air mass plummets earthward, so does the aircraft. Second, the lift that is generated by the wing is related to the relative velocity of air traveling over the wing. If the air velocity suddenly changes, so does the lift. When the lift is reduced, the aircraft descends. As an aircraft enters a microburst, depending on the point of entry, it will experience at least one of these conditions and most probably both.

The key to surviving a microburst is to enter it at a high enough aircraft energy state (high altitude and fast airspeed). The RDR-4000 system provides a warning prior to encountering the windshear, significantly improving the chances of surviving the encounter.



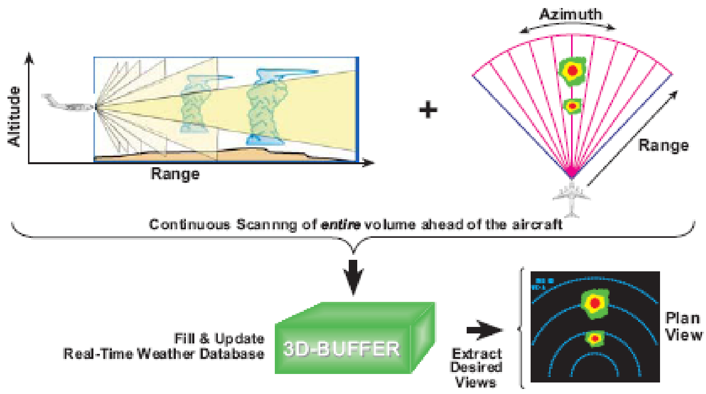
MICROBURST ENCOUNTER EXAMPLE

SECTION 6: RDR-4000 TECHNICAL OPERATION

3D VOLUMETRIC MEMORY SCANNING/PROCESSING

The RDR-4000 collects a complete 3D volumetric scan of all the weather and terrain ahead of the aircraft. The RDR-4000 contains an internal worldwide topography database, enabling it to extract ground clutter without the significant losses associated with signal-based ground clutter suppression techniques. The data in the memory is continuously updated and compensated for aircraft movement.

In conventional radar systems, there is a one-to-one real-time correspondence between the approximately 4 second side-to-side movements of the antenna, and the radar image update on the displays. In such systems, the display update is synchronized to the antenna tilt angle and sweep. Only the data needed for immediate display is collected and processed. In contrast, the RDR-4000 system has eliminated this limitation. The mechanical scanning pattern of the antenna is de-coupled from the weather images shown on the displays. The radar system continuously scans the entire 3D space in front of the aircraft, and stores all reflectivity data in 3D memory. This memory is continuously updated with reflectivity data from new scans, and the data is compensated for aircraft movement. This reflectivity data is extracted from memory to generate the selected views without having to make (and wait for) view-specific antenna scans.

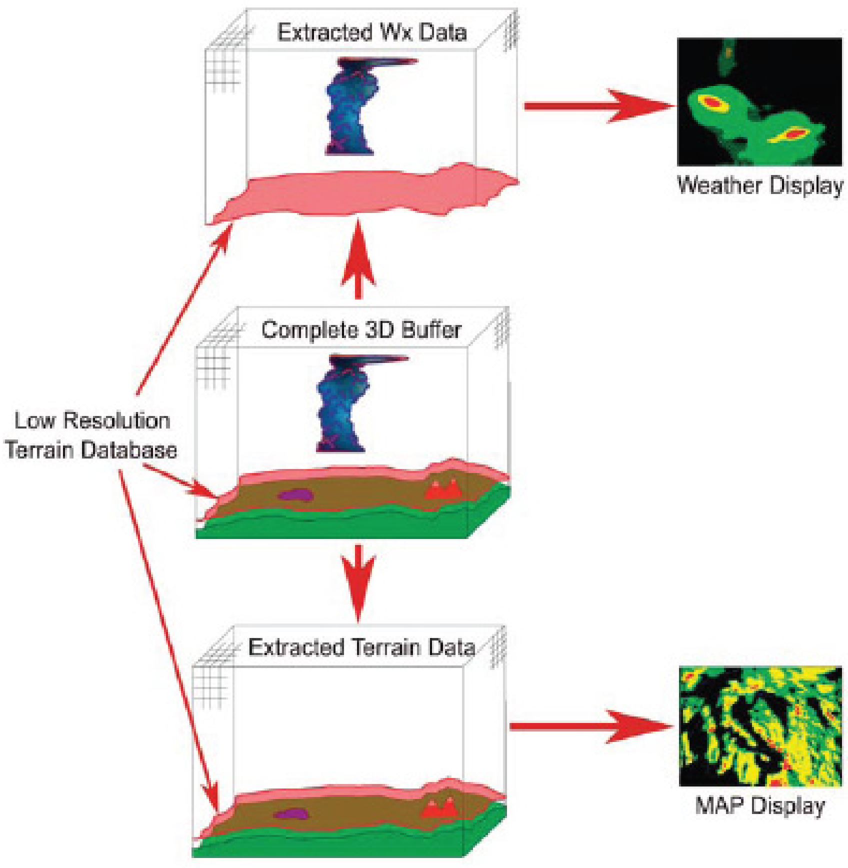


3D SCANNING AND PROCESSING

Views are no longer limited to the single diagonal slice that is inherent to conventional radars. The standard horizontal view of the radar represents a weather envelope based on flight path slope, and corrected for the curvature of the earth. Horizontal views are generated independently for each side of the cockpit.

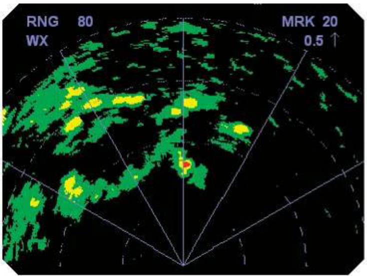
GROUND CLUTTER EXTRACTION

The radar processor contains an internal topography database with elevation data. The radar compares the collected reflectivity data with the topography database. Reflectivity data that correlates to terrain data is considered ground-clutter, and is suppressed from the weather images. However, the data that is suppressed from the weather images is retained for display when the radar's MAP Mode is selected.

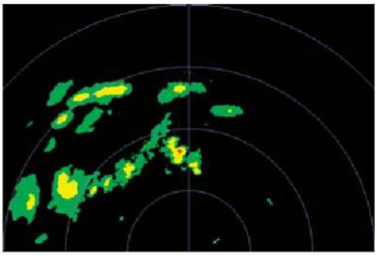


The following pictures demonstrate some of the improved features of the RDR-4000 Weather Radar System.

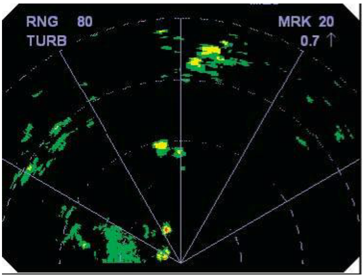
CONVENTIONAL RADAR

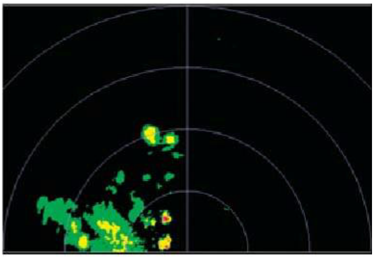


RDR-4000



IMPROVED CLUTTER REJECTION / ENHANCED WEATHER PRESENTATION





IMPROVED CLUTTER REJECTION/ENHANCED WEATHER PRESENTATION
(ALBUQUERQUE ~70 NM, RIGHT OF TRACK)

FLIGHT PATH WEATHER VS. SECONDARY WEATHER

AUTO mode is used for the strategic detection of weather. This fully automatic weather detection is enabled by the 3D volumetric memory. In this mode, “Flight Path Weather”, or weather near the altitude of the intended flight path, is displayed as distinct from “Secondary Weather”, which is further away in altitude from the flight path. The result is a presentation of weather information that is intuitive, improves awareness of the entire weather situation, and reduces the potential for misinterpretations, thus reducing crew workload.

The separation of “flight path” from “secondary” weather is based on several parameters:

- aircraft altitude
- flight phase (climb, level flight or descent)
- flight path

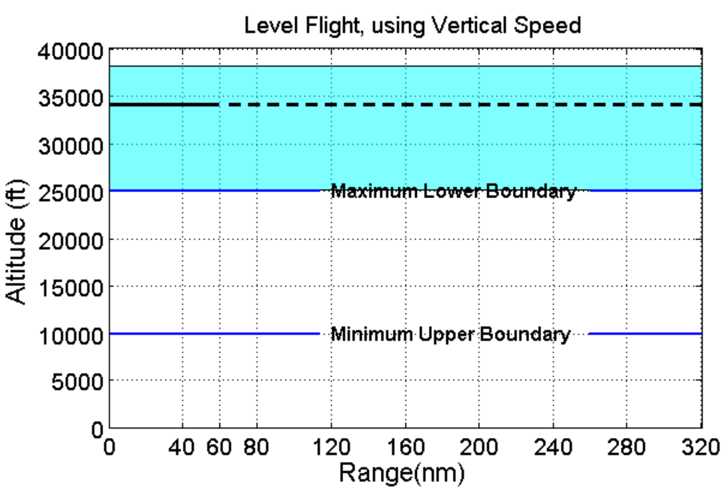
The separation is done by applying an envelope around the intended flight path: weather within the envelope is considered flight path weather; weather outside the envelope is secondary weather. On the display, secondary weather is distinguished from flight path weather by black stripes. The flight path angle is computed based on the ratio of calculated vertical speed to ground speed. The expected flight path altitude is extrapolated to 60 nm. Beyond 60 nm, level flight at the calculated altitude is assumed.

ENVELOPE BOUNDARY DEFINITION

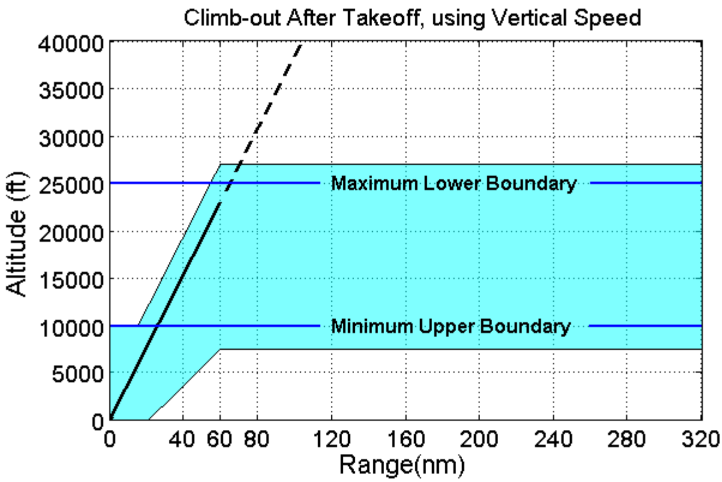
The upper and lower boundaries of the separation envelope are based on the parameters listed above. The envelope is not bounded in the horizontal plane. During level flight the envelope extends from 4000 ft above to 4000 ft below the aircraft's altitude. However, the lower boundary cannot go higher than 25,000 ft. Conversely, the upper boundary cannot go lower than 10,000 ft. Additionally, absolute envelope boundaries of 60,000 ft and ground level apply. The resulting rules are shown in the following table.

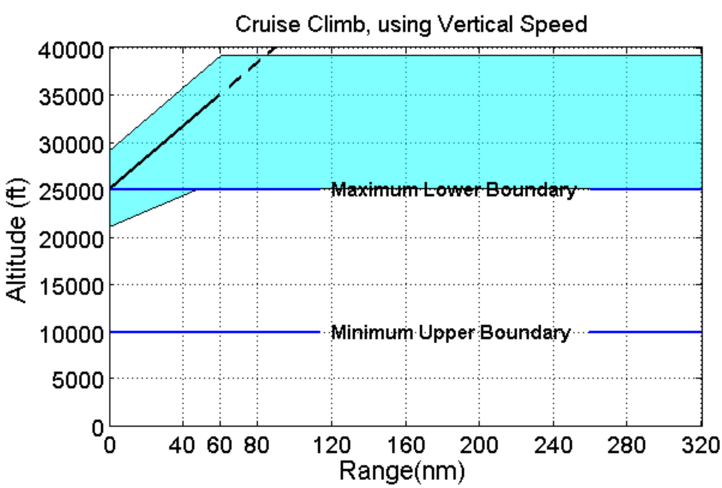
Envelope boundary limits

<table>
<tr><th>Aircraft Altitude (feet MSL)</th><th>Lower Envelope Boundary (feet MSL)</th><th>Upper Envelope Boundary (feet MSL)</th></tr>
<tr><td>> 29,000</td><td>25,000</td><td rowspan="2">Flight Altitude plus 4,000 (max. 60,000)</td></tr>
<tr><td>29,000 to 6,000</td><td rowspan="2">Flight Altitude minus 4,000 (min. ground elevation)</td></tr>
<tr><td>< 6,000</td><td>10,000</td></tr>
</table>

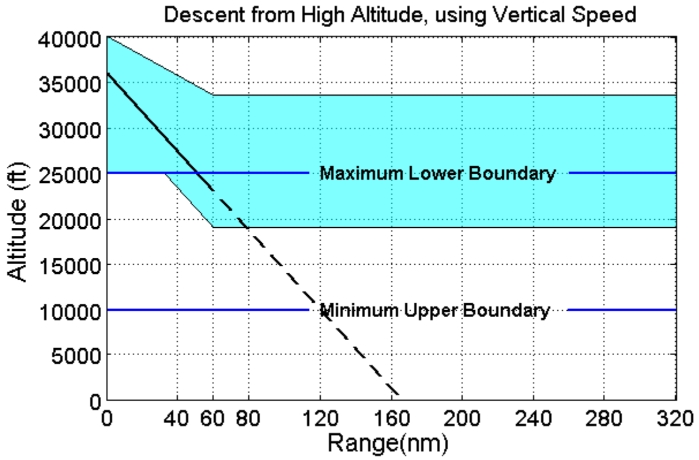


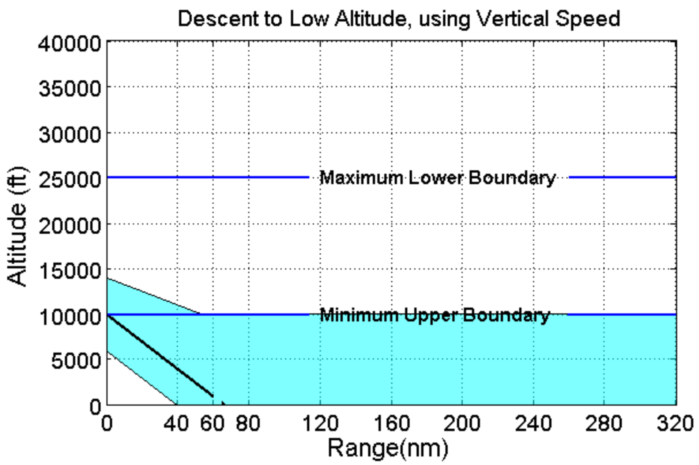
While climbing or descending the expected flight path angle for the next 60nm is determined by the ratio of vertical speed to ground speed. When climbing, the top of the envelope is 4000 ft above this expected path. However, the lower boundary is 4000 ft below ½ of the expected angle. This provides a better view of “flight path” weather near the destination altitude should the pilot level off before the 60 nm point. The envelope boundaries are still subject to the limitations shown in the table on page 54.





When descending the lower boundary of the envelope is 4000 ft below the expected path, while the upper boundary is 4000 ft above ½ of the expected angle. Again, the envelope boundaries are subject to the limitations shown in the table on page 54.

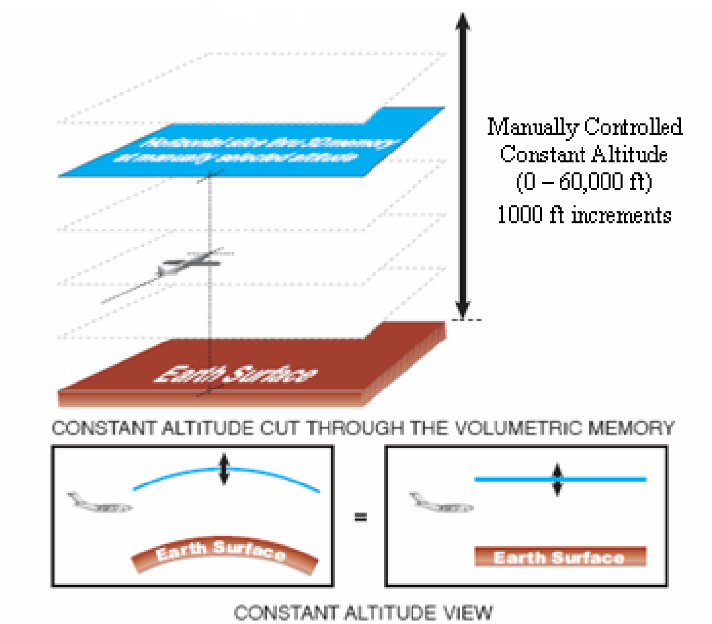




In AUTO mode, the RDR-4000 projects a three dimensional memory space onto a two dimensional display. This means the weather displayed for any one memory cell is the color of the strongest return in that column of memory cells. Specifically, if there is any weather data in a given column that is inside the envelope for "flight path" weather; the color of the strongest of these returns is displayed. If there is no weather data inside the envelope, then the color of the strongest return from outside the envelope is displayed as “secondary” weather. Stronger returns outside the envelope ("secondary" weather) never override the strongest returns displayed as "flight path" weather.

MANUAL WEATHER ANALYSIS MODE (MAN): CONSTANT ALTITUDE

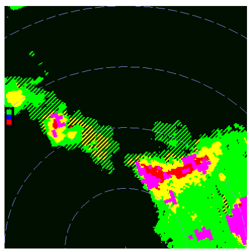
Constant altitude mode is an analysis mode providing a constant altitude slice throughout the entire 180-degree plan view. It is called constant altitude because the altitude slice extracted from the memory is corrected for the earth's curvature. With traditional tilt angle settings the earth curves away from the beam far from the aircraft making it difficult to exactly measure the height of a cell. The Constant Altitude view provides a plan view that represents a thin slice through the volumetric memory of weather reflectivity data. This view is corrected for the curvature of the earth (i.e., it is a view at a constant MSL altitude level).



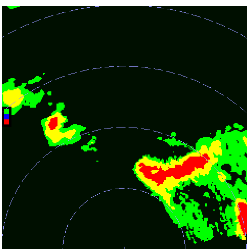
The altitude slice is selected by the ALT knob on the control panel. The altitude is selectable between zero and 60,000 ft in 1000 ft increments. Upon activation of the MAN mode, the slice at the current aircraft altitude (rounded to the nearest 1000 ft) is chosen. The view does not move up or down when the aircraft altitude changes. The pilot can quickly measure the tops of cells without any calculations. By varying the selected altitude until a cell just disappears, the cell height can be directly read from the display.

The example below demonstrates the constant altitude mode. In the top center picture the system is in the AUTO mode at an aircraft altitude of 20,000 feet MSL. In the second center picture, MAN mode has been selected, so this is an altitude slice at the current aircraft altitude (20,000 feet MSL). The remaining pictures show the returns at different altitudes. Observe that the cell tops exceed 25,000 ft. If Hazard Display is installed, Turbulence, Hail and Lightning Icons, and REACT will also be shown in Manual Mode.

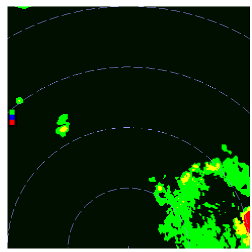
CONSTANT ALTITUDE MODE EXAMPLE
USING VARYING ALTITUDES



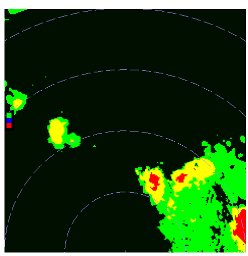
AUTO MODE



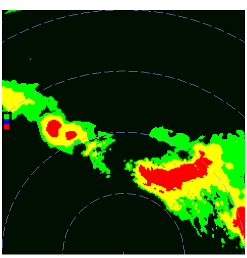
**MAN MODE:
SLICE AT 15,000 FT**



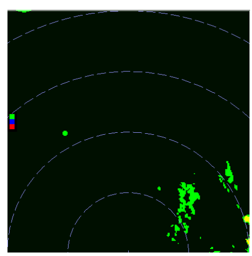
**MAN MODE:
SLICE AT 25,000 FT**



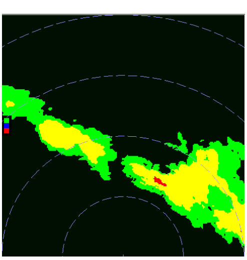
**MAN MODE:
SLICE AT 20,000FT
(AT A/C ALTITUDE)**



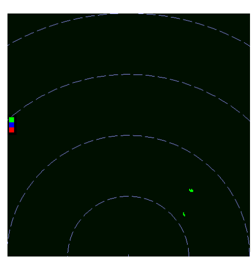
**MAN MODE:
SLICE AT 10,000 FT**



**MAN MODE: SLICE AT
30,000 FT**



**MAN MODE:
SLICE AT 5,000 FT**



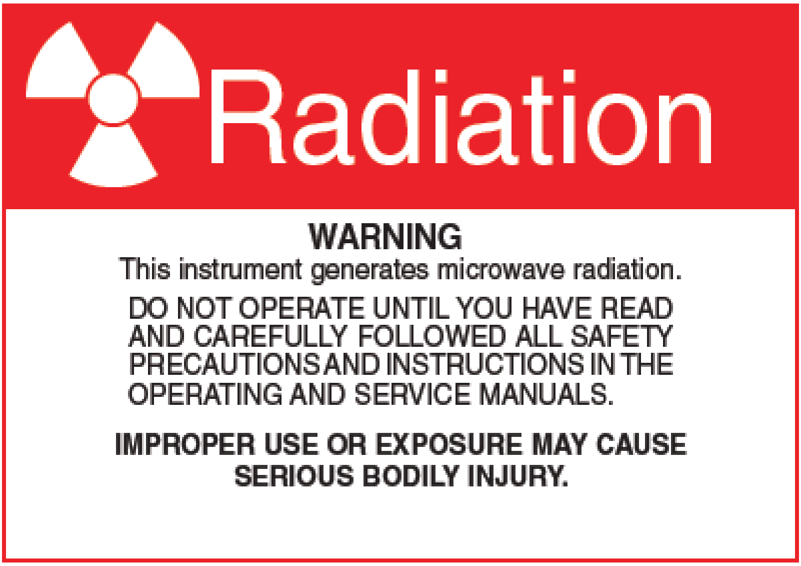
**MAN MODE: SLICE AT
45,000 FT**

PREDICTIVE HAIL AND LIGHTNING ICONS

- The hail prediction algorithm analyzes 3D weather data along with temperature data to predict cells likely to be hail producers.
- The lightning prediction algorithm is similar to that for hail prediction, but uses a slightly different reference altitude and dBz threshold.
- There is very good correlation between lightning and hail predicted by the RDR-4000 and that detected by ground-based systems.
- Predicted Lightning actually provides a leading indicator of future lightning.

APPENDIX

SAFETY INFORMATION



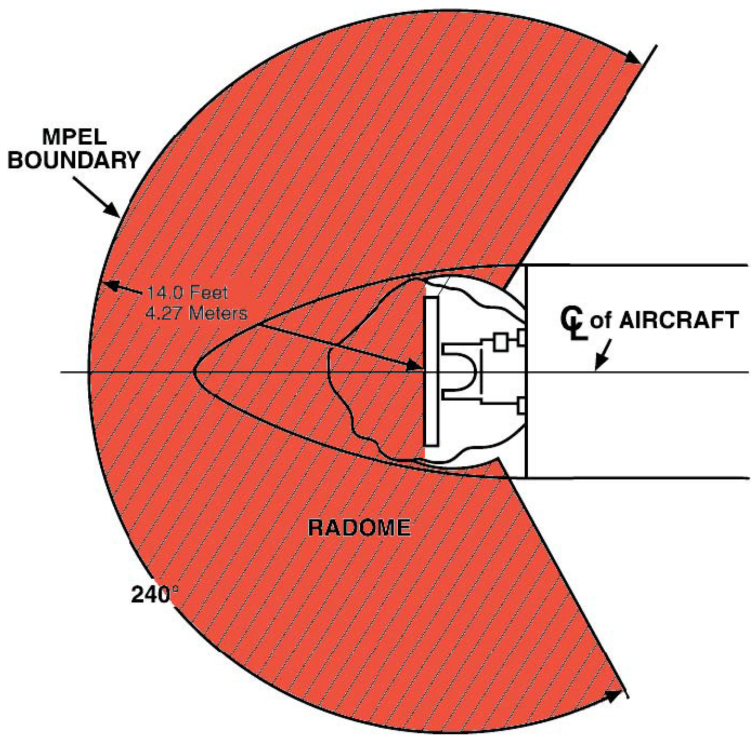
CAUTION

MAINTAIN PRESCRIBED SAFE DISTANCE WHEN STANDING IN FRONT OF A RADIATING ANTENNA.*

*Reference FAA Advisory Circular #20-68B

MAXIMUM PERMISSIBLE EXPOSURE LEVEL (MPEL)

FAA advisory circular AC 20-68B defines the method for determining the MPEL boundary. All personnel should remain beyond the distance indicated in the illustration below. Manufacturers are required to calculate two distances; the MPEL boundary is determined by the greater of these two distances. The first distance is the near field/far field boundary which is the distance from the antenna that it takes for the beam to form. For the RDR-4000 this distance is 14 feet (4.27 meters). The second is the distance where the radiation level exceeds the U.S. Government standard of 10 milliwatts per square centimeter. For the RDR-4000 this distance is 11.8 feet (3.58 meters) from the antenna. In TEST mode the system transmits two 550 microsecond pulses at the beginning of the test sequence and the safe distance is 0.8 inches (2.1 centimeters) from the antenna during this period. The safe fuel distance is 3.5 feet (1.07 meters) from the antenna.



MPEL BOUNDARY

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